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(54) PLASMA PROCESSING APPARATUS

(76) Inventor: Masaki Suzuki, Osaka-fu (JP)

Correspondence Address:
WENDEROTH, LIND & PONACK, L.L.P.
2033 K STREET N. W.
SUITE 800
WASHINGTON, DC 20006-1021 (US)

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(57) ABSTRACT

A plasma processing apparatus includes a process chamber, a preliminary chamber which is disposed along a direction inclined with respect to a center axis of the process chamber and which is interruptibly communicated with the process chamber, a substrate electrode portion having a substrate placement surface on the top surface of which the substrate can be placed, a substrate electrode moving device for moving the substrate electrode portion between a plasma processing position within the process chamber and a substrate delivery position within the preliminary chamber while maintaining the substrate placement surface generally horizontal, and a lid portion which is provided in the preliminary chamber so as to be openable and closable. The substrate electrode moving device is operable to move the substrate electrode portion between the plasma processing position and the substrate delivery position along the inclined direction.

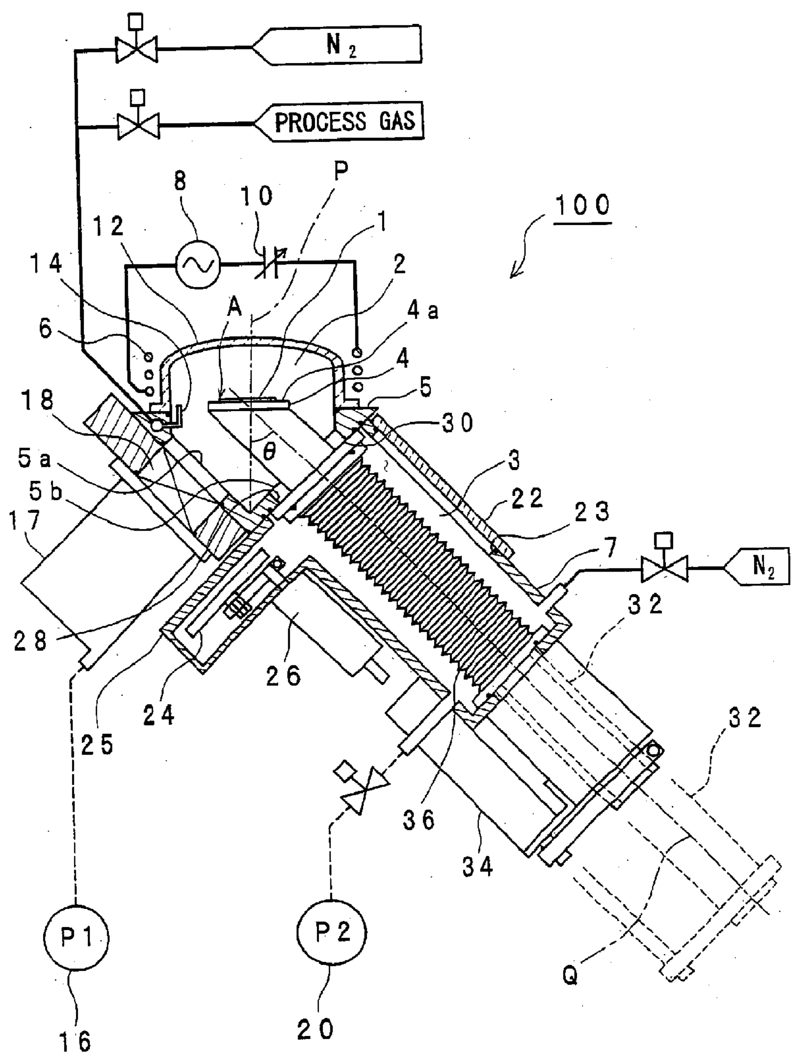
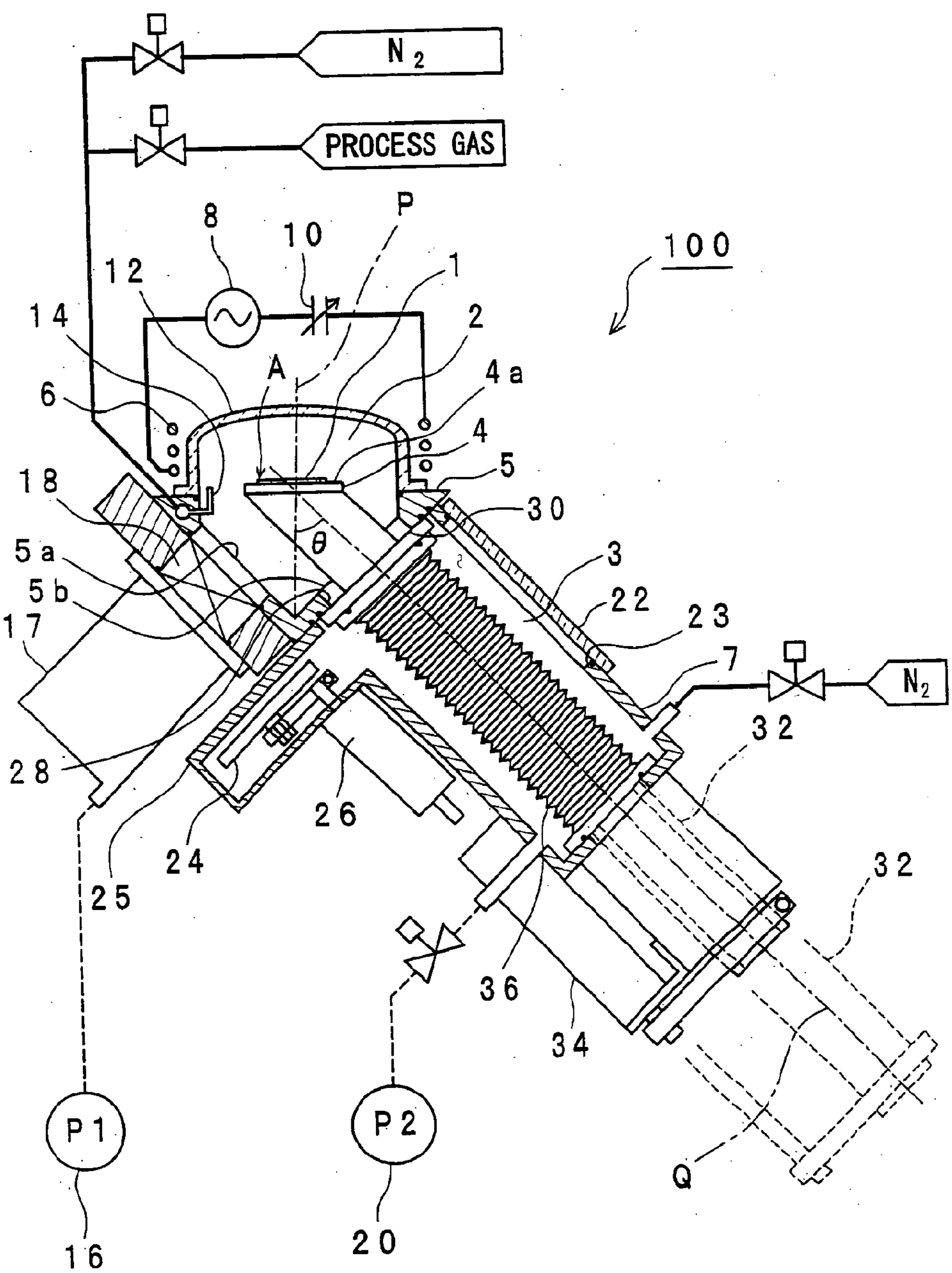


Fig. 1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5b
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P1
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Fig. 2

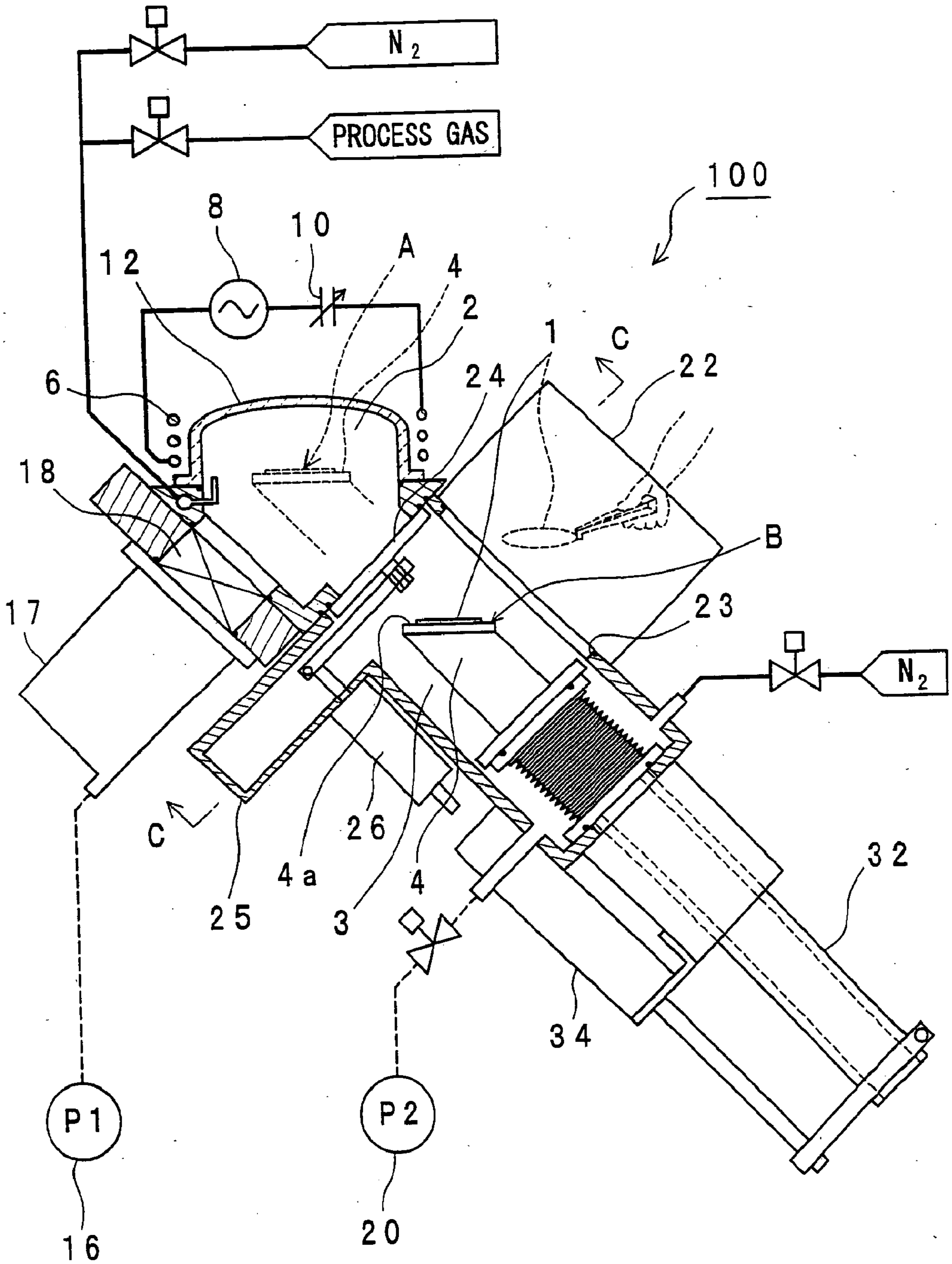
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Fig. 3

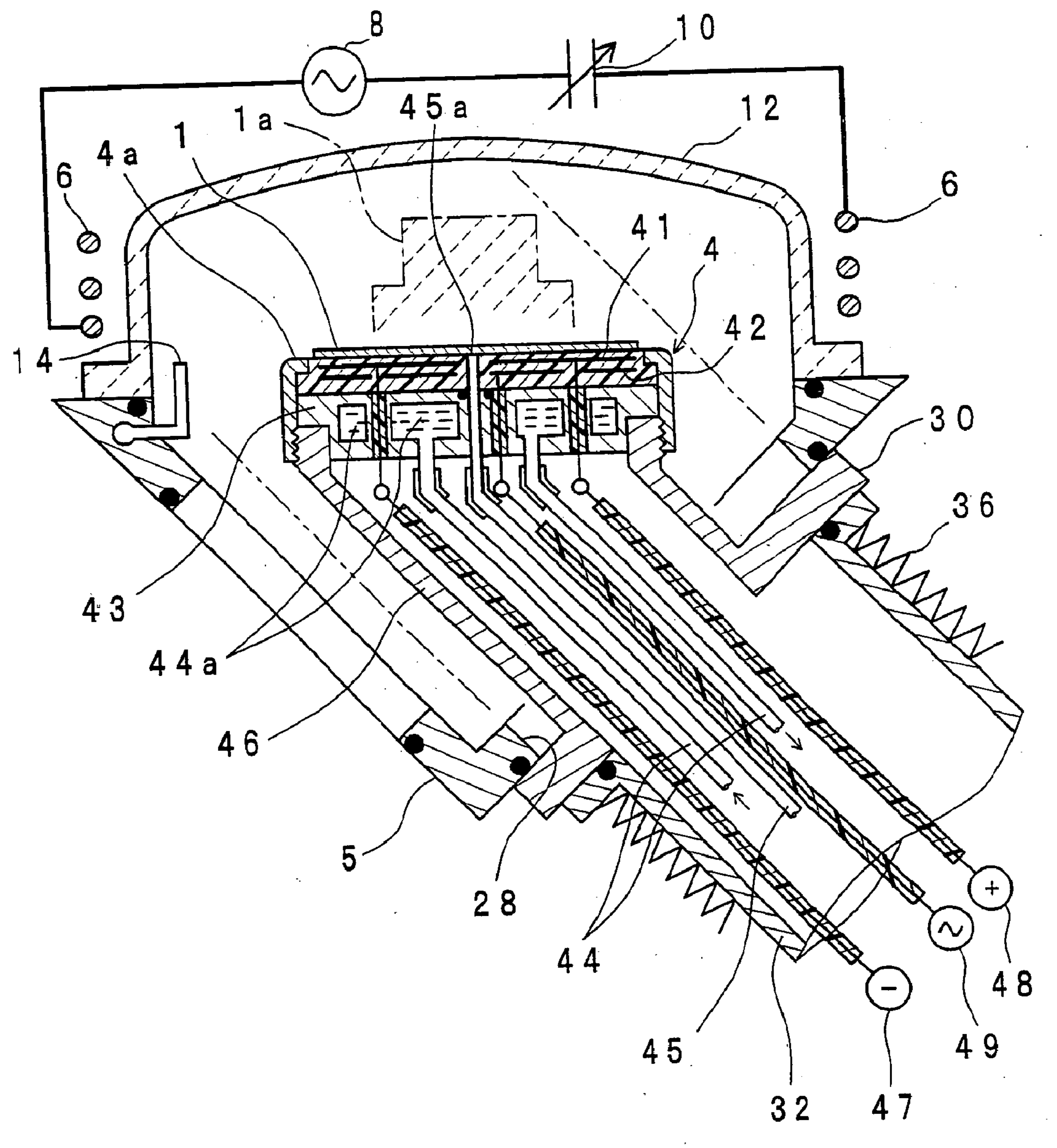


Fig. 4

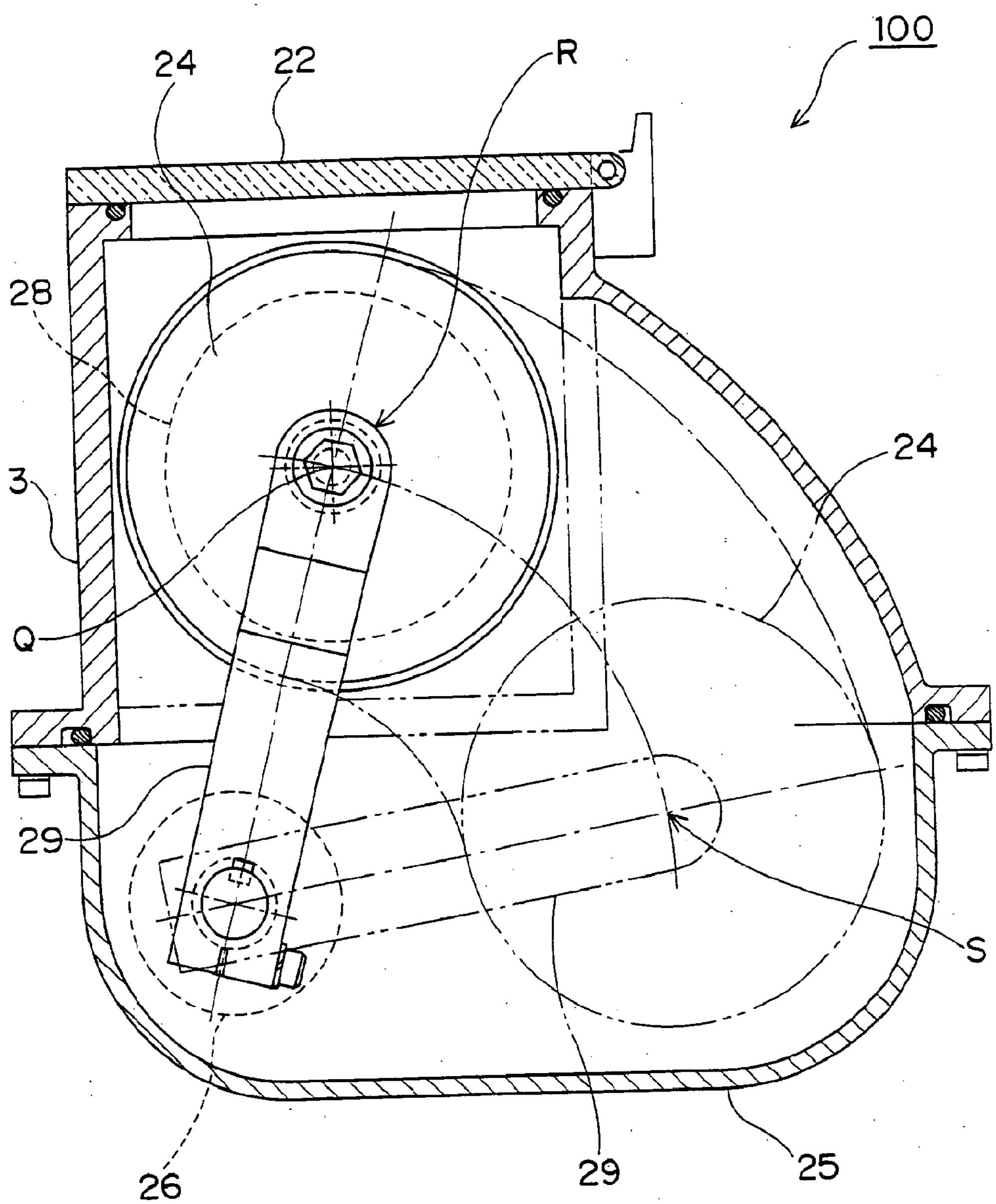


Fig. 5

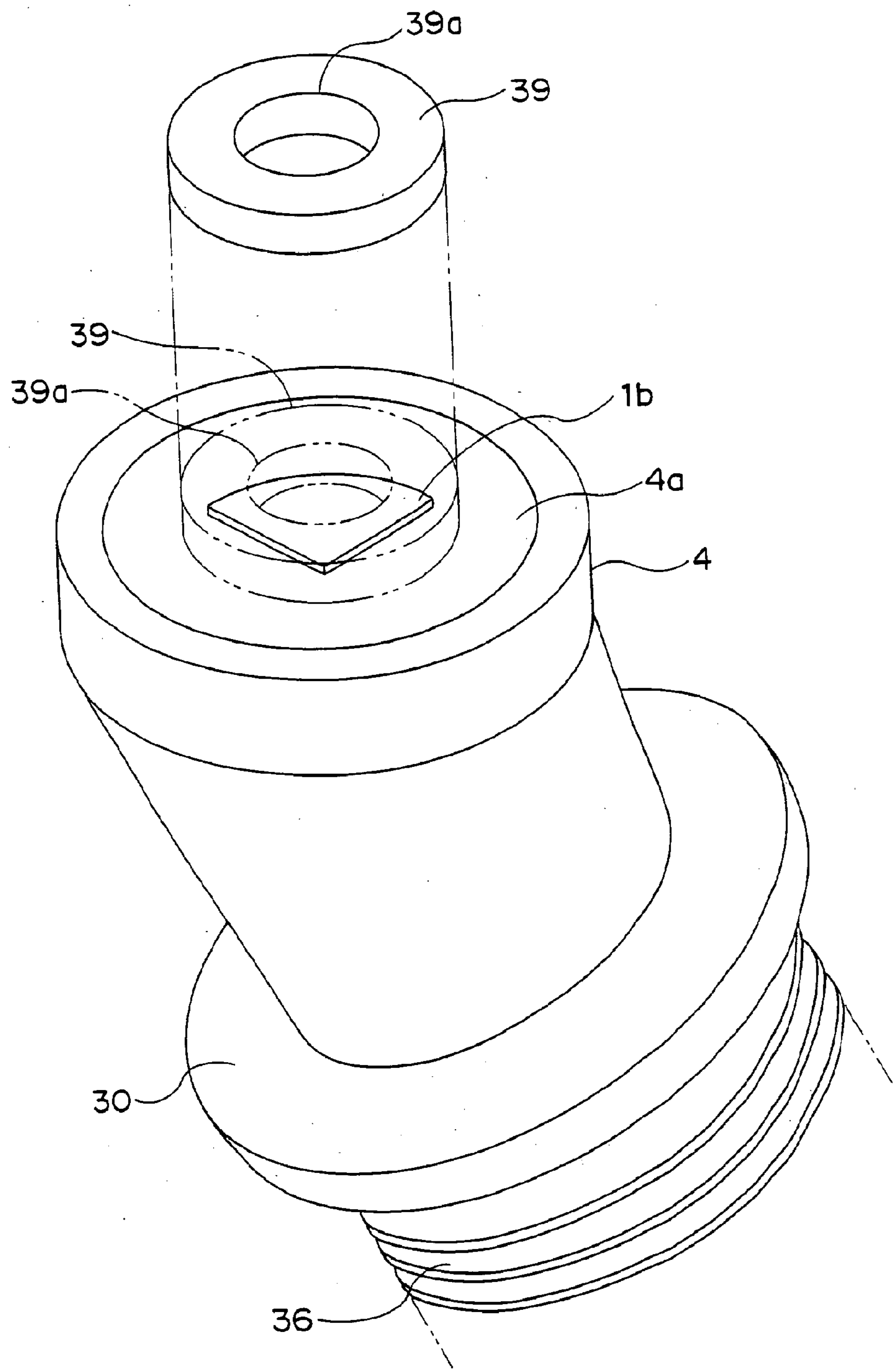
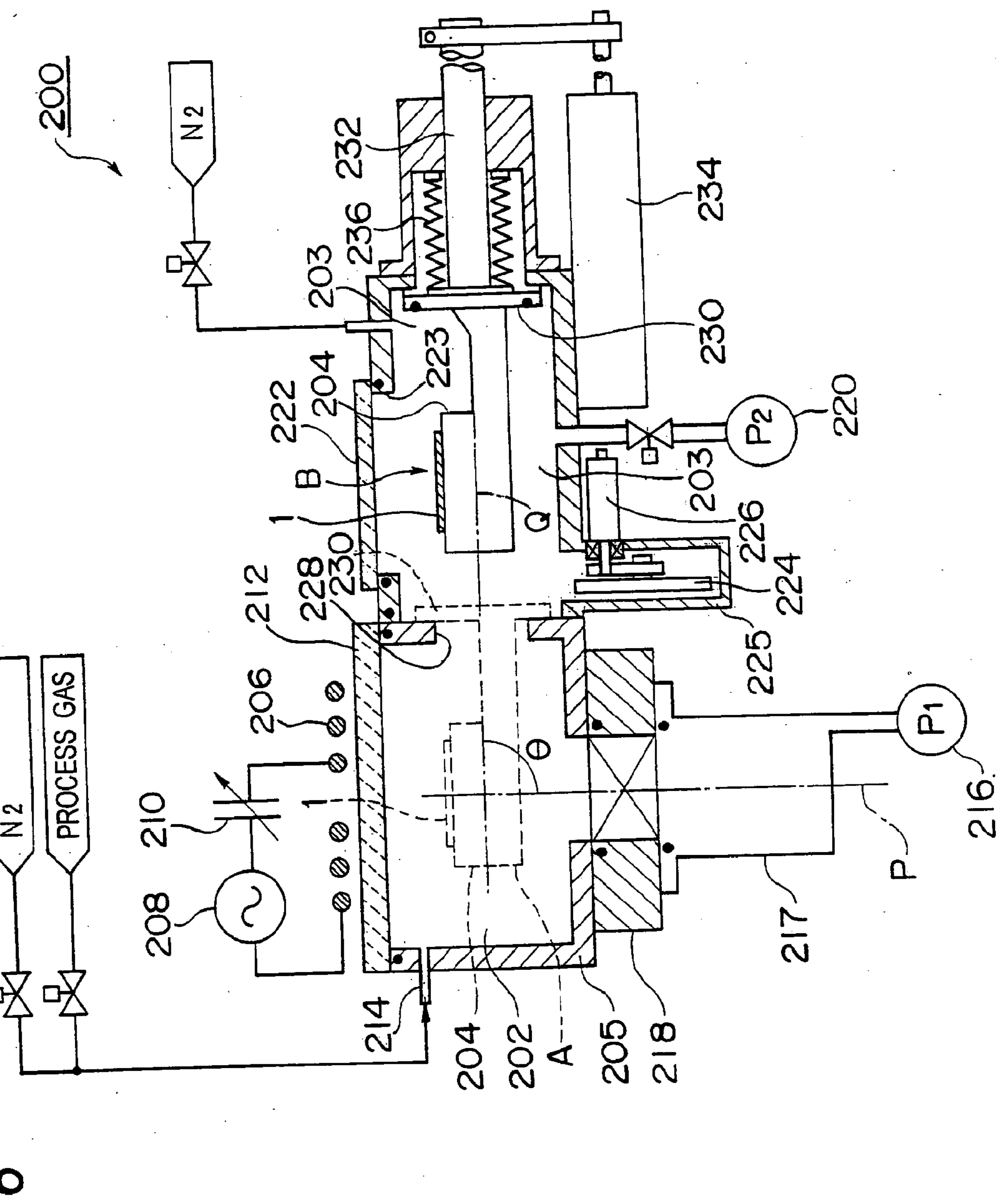


Fig.6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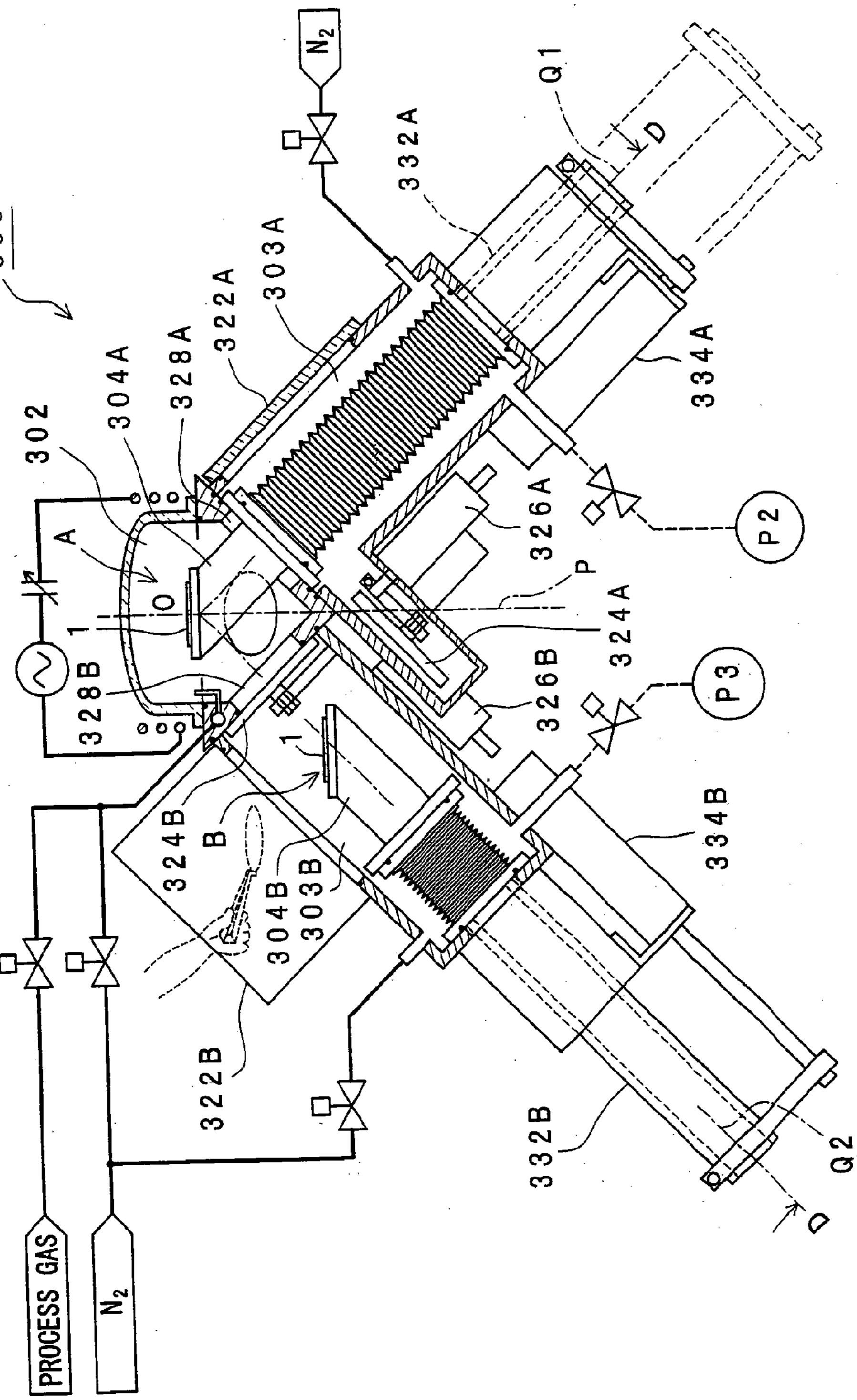
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334B
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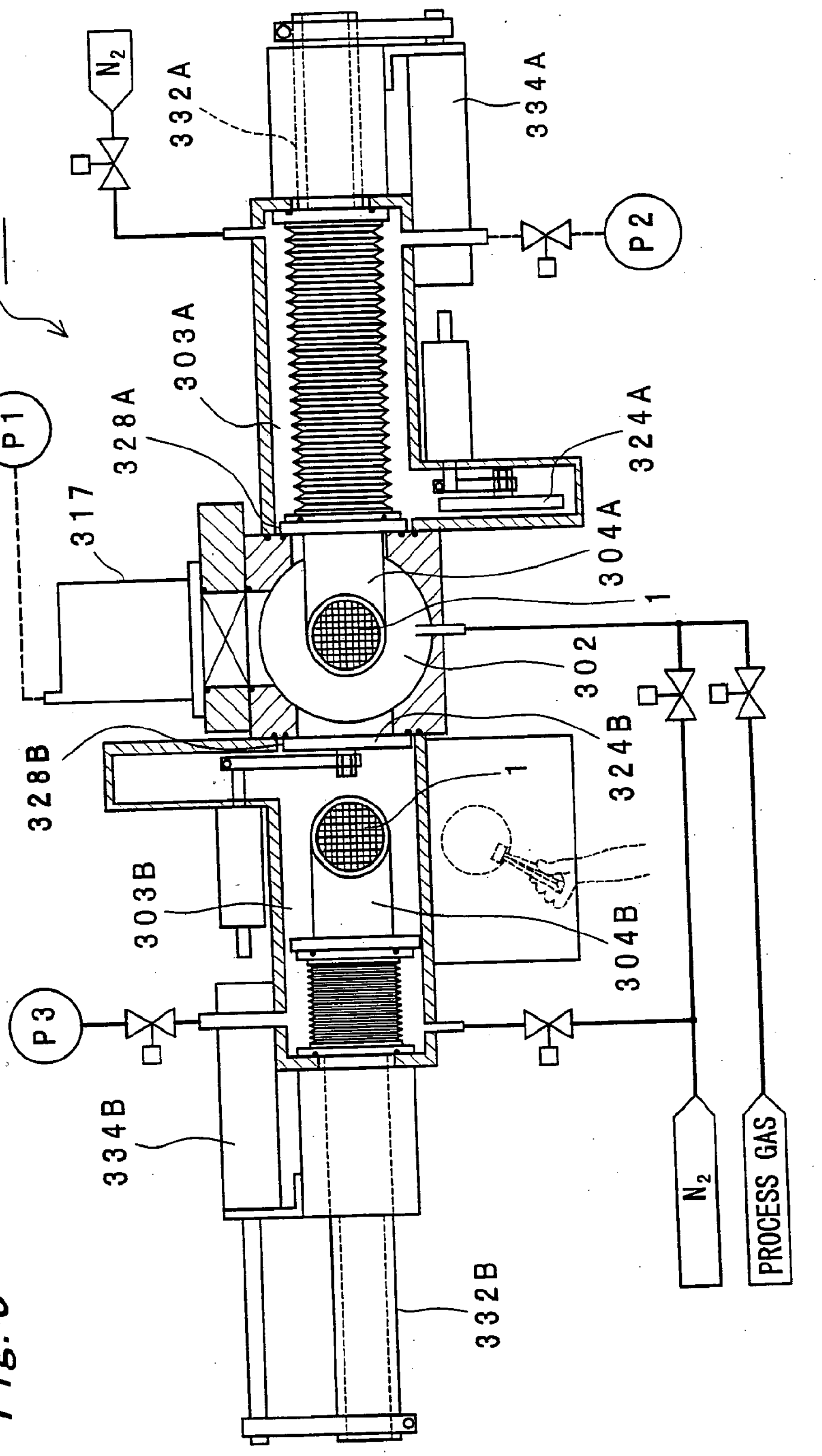
Fig. 7

Fig. 8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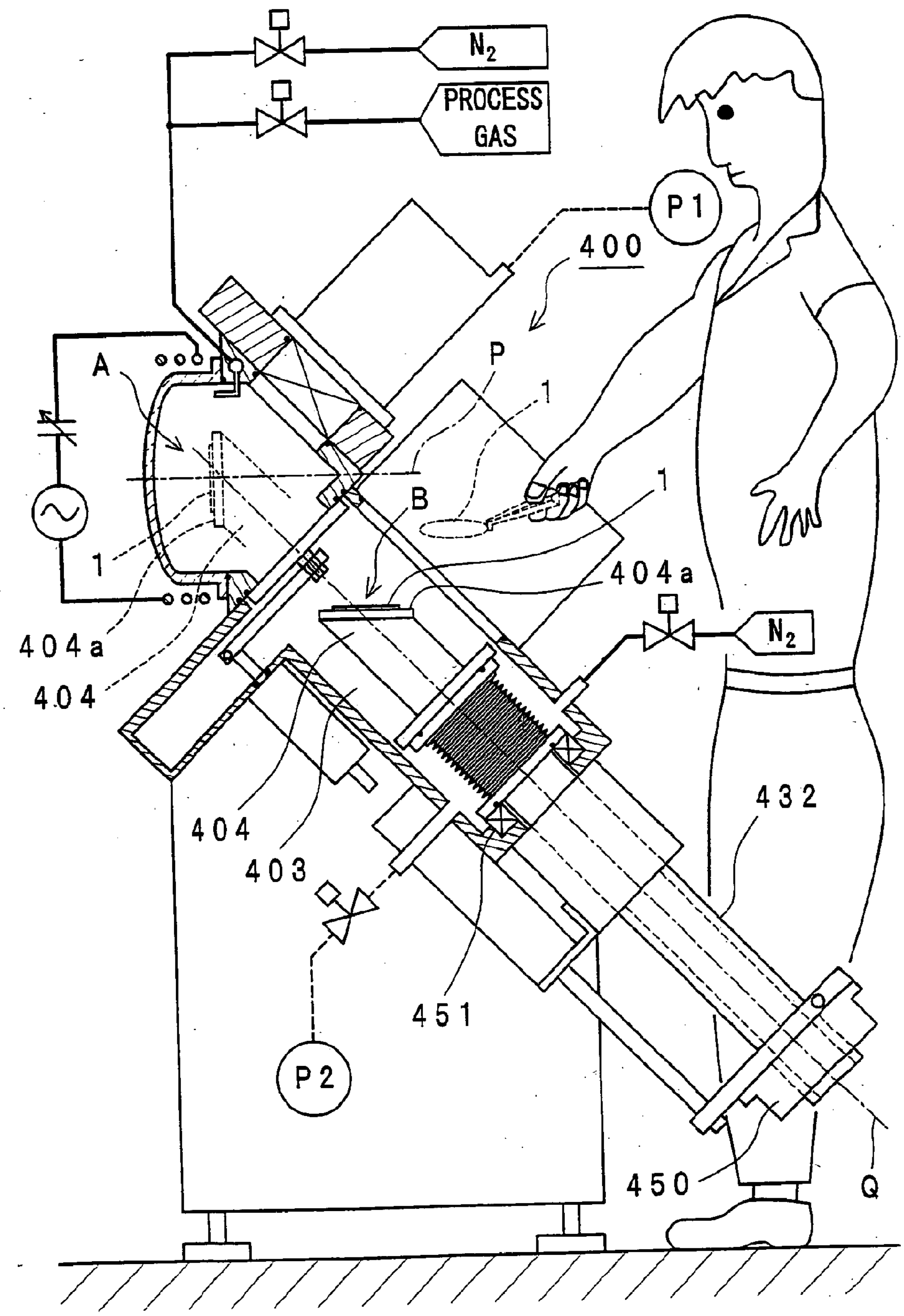
332B
N_2
PROCESS GAS

Fig. 9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P2
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Q

Fig. 10

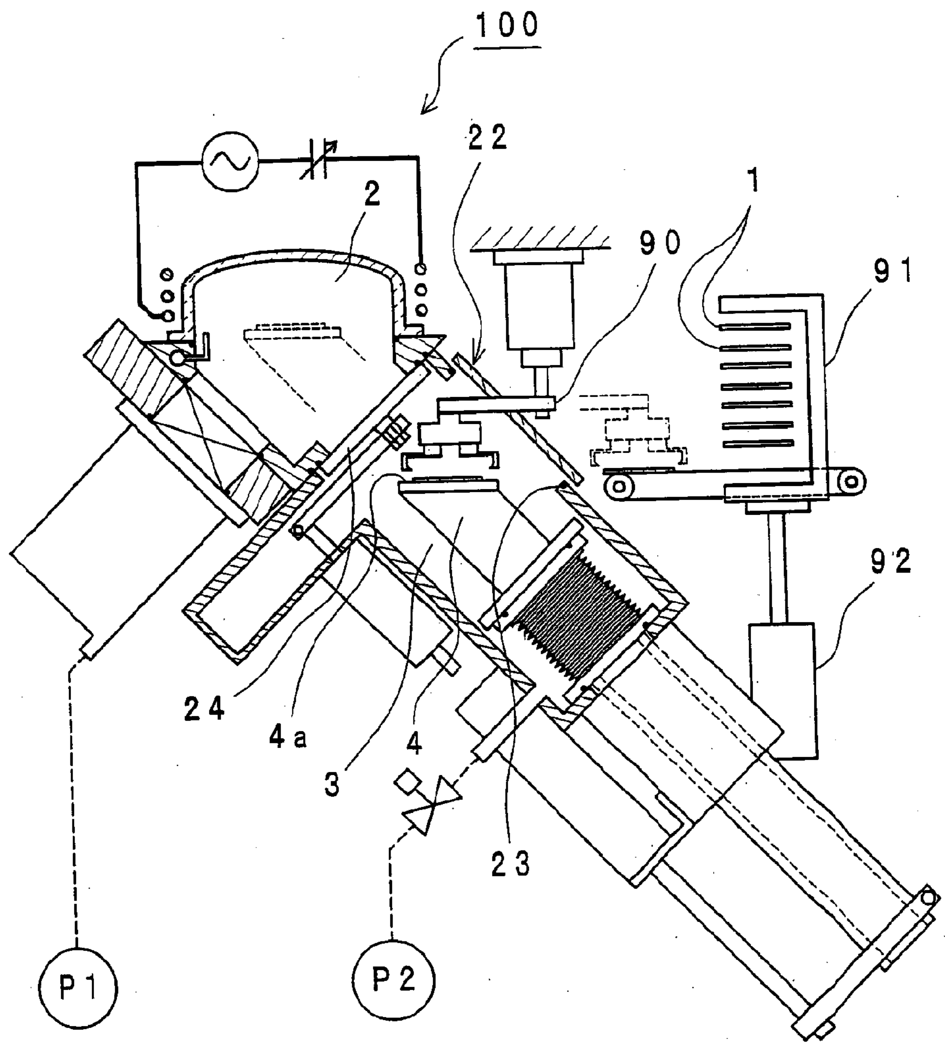


Fig.11 PRIOR ART

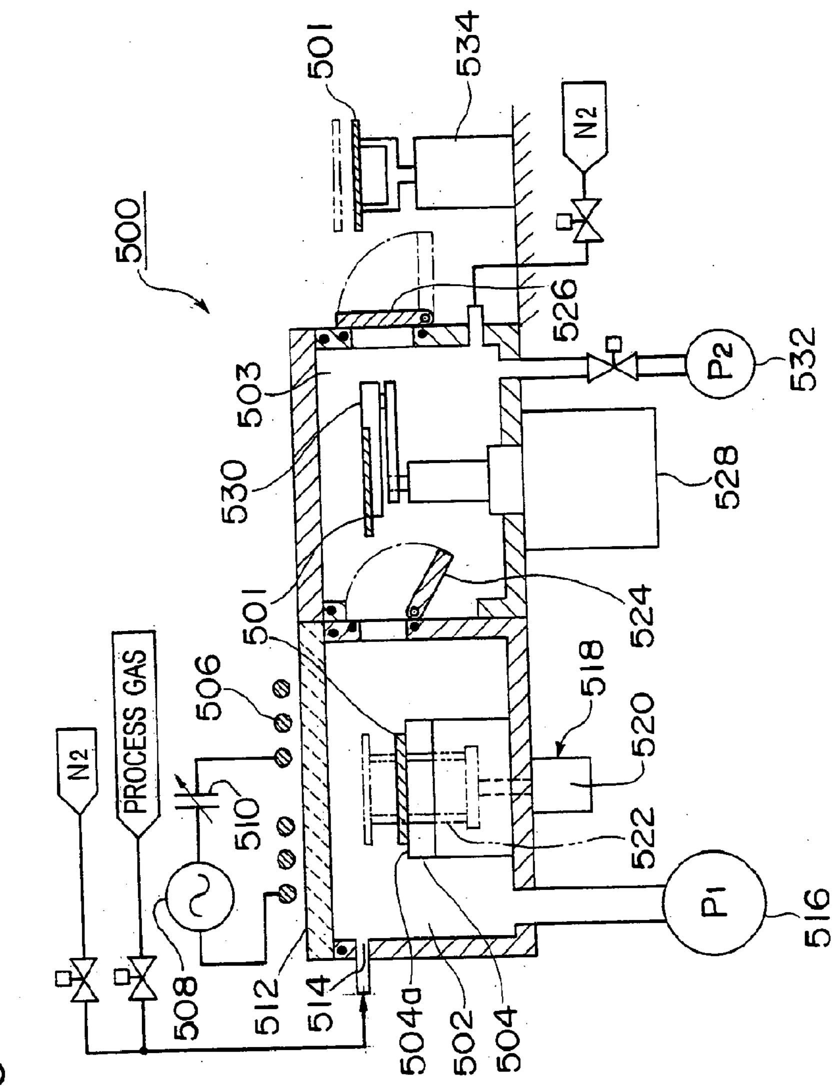


Fig.12 PRIOR ART

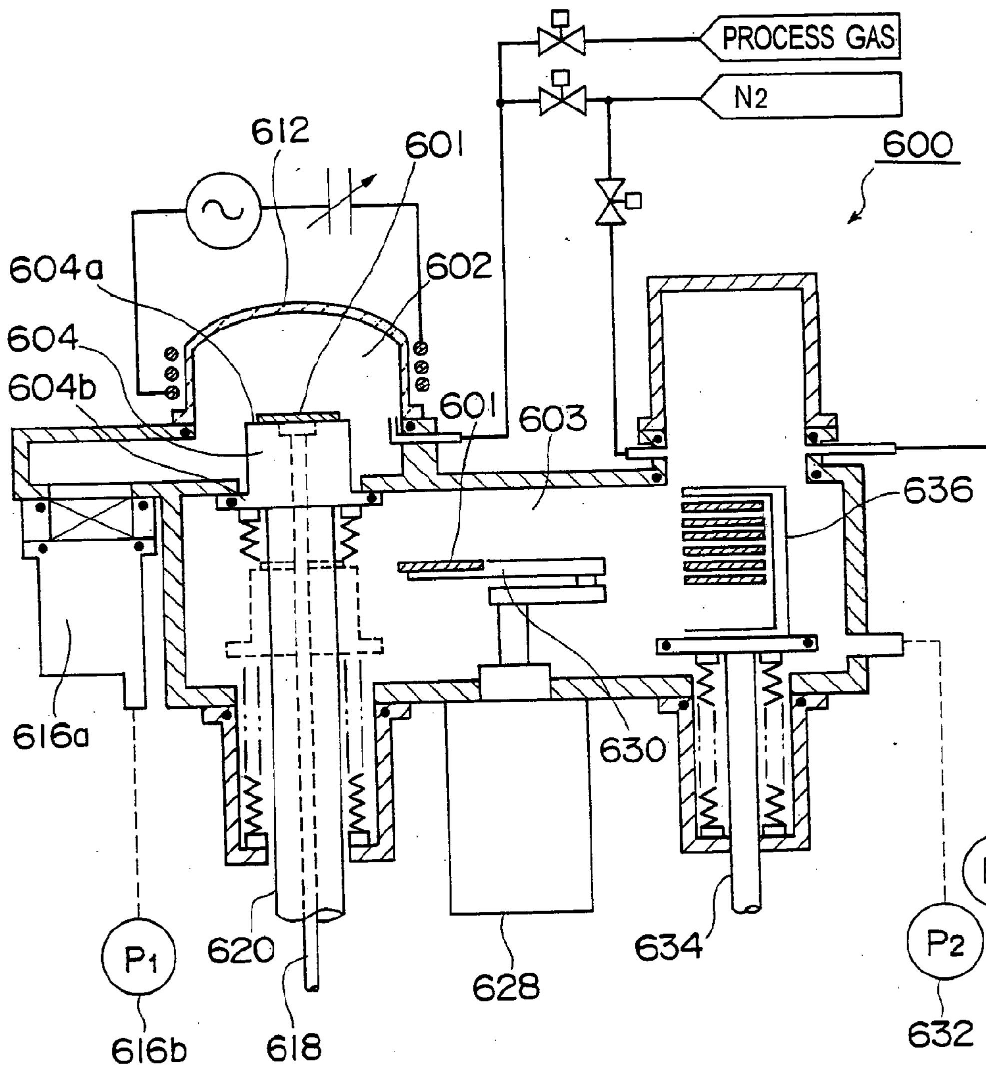
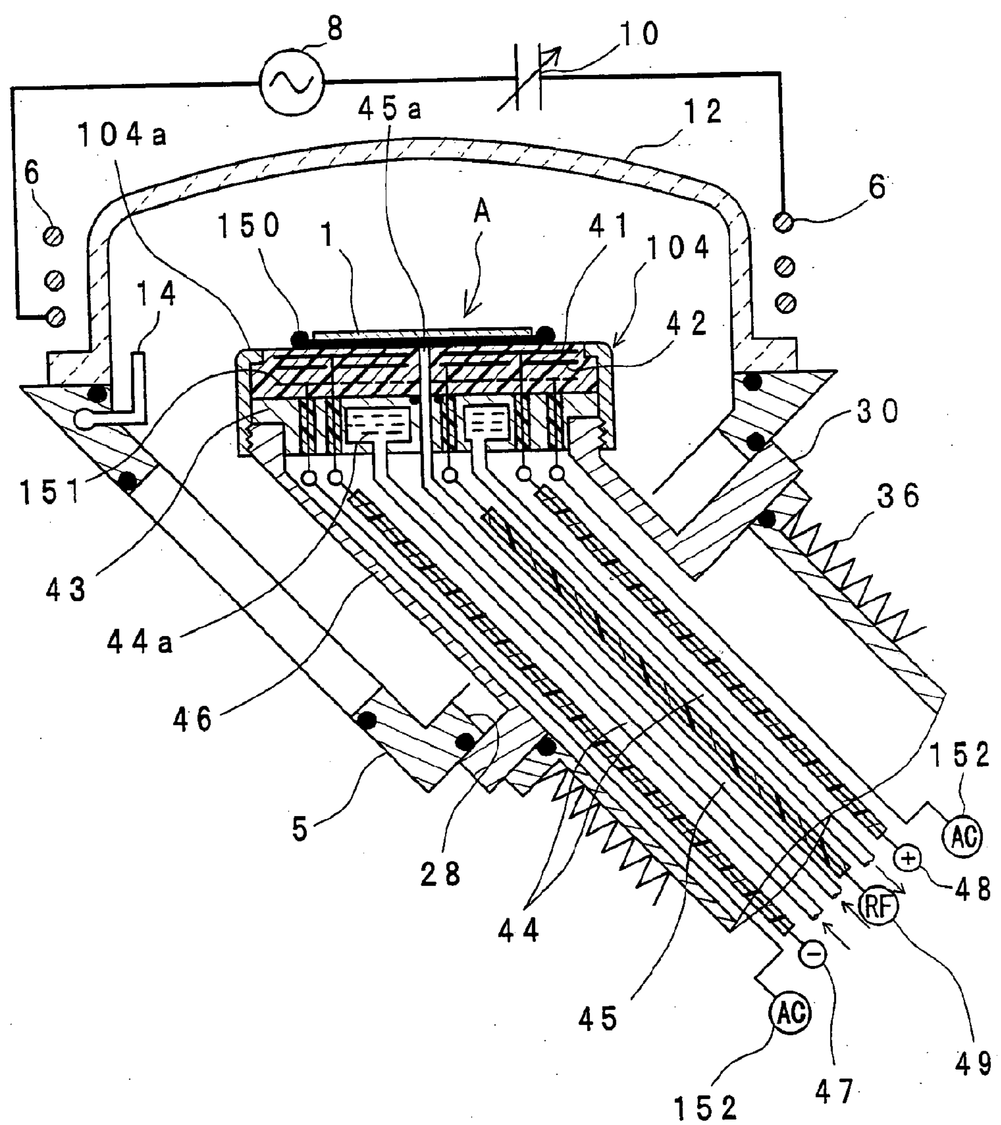


Fig. 13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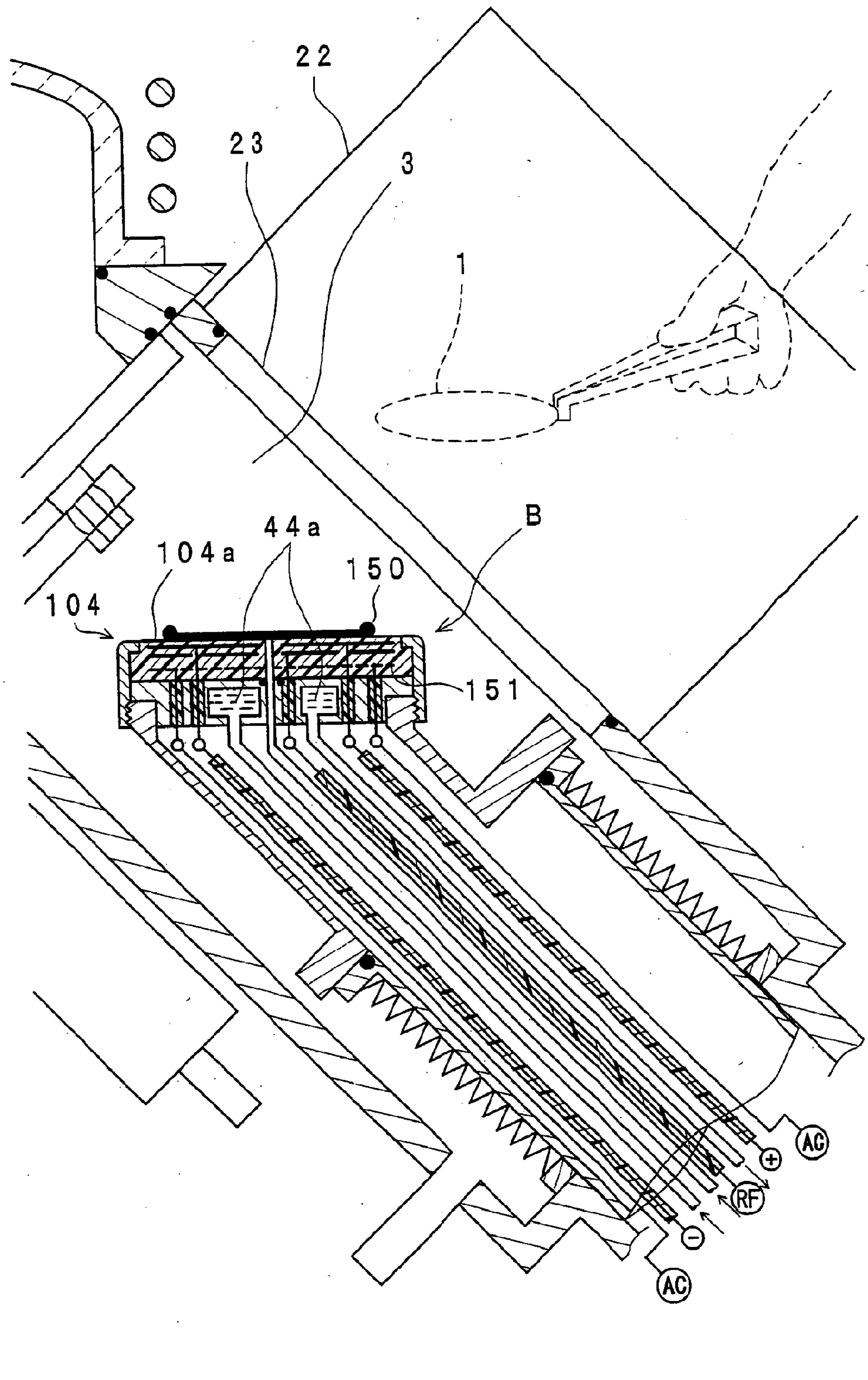
44
AC
45
47
49
152

Fig. 14



PLASMA PROCESSING APPARATUS

BACKGROUND OF THE INVENTION

[0001] The present invention relates to plasma processing apparatuses such as dry etching apparatuses, plasma CVD apparatuses or sputtering apparatuses to be used for the manufacture of semiconductor or other thin-film circuits or electronic circuits.

[0002] (Prior-Art Plasma Processing Apparatus 1)

[0003] As this type of plasma processing apparatus, a variety of apparatuses have been known conventionally. As an example of such a prior-art plasma processing apparatus, a schematic view showing a schematic construction of a plasma processing apparatus **500** is shown in **FIG. 11**.

[0004] As shown in **FIG. 11**, with respect to a wafer **501** which is an example of substrates (workpieces), the plasma processing apparatus **500** is provided with a process chamber **502**, which is a sealable chamber to be subject to plasma processing and a load lock chamber **503** which is a chamber to be interposed between the process chamber **502** and the exterior of the apparatus, i.e. the atmospheric space, where the load lock chamber **503** is interruptibly communicated with the process chamber **502**.

[0005] The process chamber **502** is provided with: a lower electrode **504** having a placement surface **504***a* on which the wafer **501** is to be placed; a first rotary pump **516**, which is an example of vacuum evacuator for evacuating the internal space of the process chamber **502** to a vacuum; a gas inlet **514** for supplying reactant gas into the process chamber **502**; and a quartz window **512** which forms part of an outer wall of the process chamber **502** and which is placed above the placement surface **504***a*. Within the lower electrode **504**, a heating/cooling medium circulation part (not shown) is provided to control the temperature of the substrate placement surface **504***a*. Further, piping (not shown) for supplying a heat transfer gas such as He from within the lower electrode **504** is provided on the substrate placement surface **504***a* to accelerate the heat transfer between the substrate **501** and the substrate placement surface **504***a*.

[0006] Above the quartz window **512** outside the process chamber **502**, a coil **506** which is connected to a radio-frequency power, supply **508** and a matcher **510** and to which a radio-frequency power can be applied is placed so as to face the lower electrode **504** within the process chamber **502**.

[0007] The load lock chamber **503**, which is placed on the right side of the process chamber **502** as viewed in the figure, is interruptibly communicated with the process chamber **502** via an openable-and-closable vacuum-side gate **524**. Further, the load lock chamber **503** is provided with an atmosphere-side gate **526** which is openable and closable for the outside space of the apparatus. Outside the apparatus in proximity to the atmosphere-side gate **526**, is provided a wafer lifter **534** on which the wafer **501** is to be placed so as to be deliverable to and from the load lock chamber **503** through the atmosphere-side gate **526**. Also in the load lock chamber **503** is provided a carrier robot **528** which works for holding the wafer **501** placed on the wafer lifter **534** by its robot arm **530** and then carrying it into the load lock chamber **503** through the atmosphere-side gate **526** and for carrying the wafer **501** into the process chamber **502** through the vacuum-side gate **524** and further placing the wafer **501** on the placement surface **504***a*. This carrier robot **528** is enabled to pick out the plasma-processed wafer **501** from the placement surface **504***a* by the robot arm **530** and carry it out to the outside of the apparatus through the vacuum-side gate **524** and the atmosphere-side gate **526**. Further, in the load lock chamber **503** is provided with a second rotary pump **532** which is an example of the vacuum evacuator for evacuating the internal space of the load lock chamber **503** to a vacuum.

[0008] The lower electrode **504** of the process chamber **502** is provided with a push-up device **518** for pushing up the wafer **501** placed on the placement surface **504***a* from its lower side to make the wafer **501** levitated from the placement surface **504***a*. The push-up device **518** is equipped with a plurality of push-up pins **522** for pushing up the underside of the wafer **501**, and a cylinder portion **520** for moving up and down these push-up pins **522**.

[0009] The prior-art plasma processing apparatus **500** as described above is enabled to perform plasma processing on the wafer **501** that has been carried and placed on the placement surface **504***a* of the lower electrode **504** by the robot arm **530**, and to make the processed wafer **501** levitated from the placement surface **504***a* by the push-up device **518** and further scooped up and carried by the robot arm **530**, then extracted from the process chamber **502** (see, e.g., Japanese unexamined patent publication No. H8-124901 (**FIG. 2**)).

[0010] (Prior-Art Plasma Processing Apparatus 2)

[0011] Next, **FIG. 12** shows a schematic view showing a schematic construction of a plasma processing apparatus **600** according to another prior-art example.

[0012] As shown in **FIG. 12**, the plasma processing apparatus **600** is similar to the plasma processing apparatus **500** in having a process chamber **602** and a load lock chamber **603**, but differs from the plasma processing apparatus **500** structurally in that a lower electrode **604** is movable (up-and-down movable) between the process chamber **602** and the load lock chamber **603**.

[0013] More specifically, as shown in **FIG. 12**, the process chamber **602** is equipped with a turbo-pump **616***a* and a first rotary pump **616***b* for evacuating interior of the process chamber **602**, and a dielectric bell jar **612** which is placed at the upside of the process chamber **602** and which forms part of the process chamber **602**. The lower electrode **604**, whose upper face serves as a placement surface **604***a* for a wafer **601**, is equipped with an electrode lifter **620** which moves up and down the placement surface **604***a* between a plasma processing position for the wafer **601** in the process chamber **602** and a feed-extraction position which is a position within the load lock chamber **603** below the plasma processing position and which is a position where a robot arm **630** of a carrier robot **628** feeds and extracts the wafer **601** onto the placement surface **604***a*. Further, at a lower portion of the lower electrode **604** is provided an interruption part **604***b* which can interrupt the communication between the process chamber **602** and the load lock chamber **603** by contact with part of the outer wall of the process chamber **602** while the placement surface **604***a* is located at the plasma processing position. As a result of this, moving the lower electrode **604** to the plasma processing position by the electrode lifter **620**

allows the communication between the process chamber **602** and the load lock chamber **603** to be interrupted, while moving the lower electrode **604** to the feed-extraction position allows the interruption to be released.

[**0014**] In the load lock chamber **603** are provided a second rotary pump **632** for evacuating interior of the load lock chamber **603** to a vacuum, and a wafer cassette **636** for extractably accommodating therein a plurality of wafers **601**. Further provided is a cassette lifter **634** for lifting and lowering the wafer cassette **636** so that a desired wafer **601** can be extracted from among the wafers **601** accommodated in the wafer cassette **636** by the robot arm **630**.

[**0015**] Furthermore, in the lower electrode **604** and the electrode lifter **620** is provided with a push-up device **618** for pushing up the wafer **601** placed on the placement surface **604***a* from the lower face of the wafer **601**, where the function of this push-up device **618** is similar to that of the push-up device **518** of the plasma processing apparatus **500** (see, e.g., Japanese unexamined patent publication No. 2002-299330 (**FIG. 12**)). Further, within the lower electrode **604**, a heating/cooling medium circulation part (not shown) is provided to control the temperature of the substrate placement surface **604***a*. Besides, piping (not shown) for supplying a heat transfer gas such as He from within the lower electrode **604** is provided on the substrate placement surface **604***a* to accelerate the heat transfer between the substrate **601** and the substrate placement surface **604***a*.

SUMMARY OF THE INVENTION

[**0016**] In recent years, there has been being made vigorous technological development for wafer or other substrates. Processes of such technological development, in many cases, involve plasma processing exerted on substrates or the like, and such plasma processing apparatuses have been finding more opportunities for not only conventional mass production use but also, principally, experiment, development and small-quantity production uses.

[**0017**] In such experiment, development and small-quantity production uses, wafers to be processed are not necessarily limited to disc-shaped ones, but often given by subdivided disc-shaped wafers or other special-shaped workpieces (substrates).

[**0018**] Therefore, in the prior-art plasma processing apparatus **500** or **600**, for the plasma processing to be performed on such an abnormally shaped wafer (workpiece), there are some cases where in consideration of the handlability of the abnormally shaped wafer in its conveyance by the carrier robot **528**, **628**, for example, the abnormally shaped wafer as it is stuck to an upper surface of another disc-shaped wafer is carried by the carrier robot, in which state the plasma processing on the abnormally shaped wafers is performed.

[**0019**] In such a case, there are problems that the plasma processing would involve time for bonding and separating the wafer to and from the other disc-shaped wafer, and moreover that the abnormally shaped wafer, being stuck to the surface of the other disc-shaped wafer, would lower in its thermal conductivity to the lower electrode **504**, **604**, thus making it impossible to achieve proper plasma processing.

[**0020**] Further, in the prior-art plasma processing apparatuses **500** and **600**, after subjected to the plasma processing, the wafer may often be electrified, often making it difficult to mechanically push up, for example, a compound semiconductor wafer **501**, **601** having properties of thinness and weak strength without damaging the wafer and with a 100% reliability, for the push-up device **518**, **618** that performs the operation of pushing up the wafer in close contact with the placement surface to thereby make the wafer levitated from the placement surface **504***a*, **604***a*. Also, the carrier robot arm **530**, **630** that operates in a vacuum chamber is susceptible to small effects of the material, film quality, size, residual charge and the like of an object to be carried by the carrier robot arm **530**, **630**, so that occurrence of operation errors such as a fall of the carrying object from the robot is unavoidable during continued use.

[**0021**] For a vacuum plasma processing apparatus, once a wafer fall or the like due to wafer damage in a push-up the wafer row carrying troubles of the robot arm as described above has occurred, it would be necessary that the process chamber **502**, **602**, which should be kept normally at a vacuum, is set to atmospheric pressure by blowing in nitrogen gas via the gas inlet, and thereafter the quartz window **512** or bell jar **612** is removed to make the process chamber opened to the air for collection of wafer fragments. In such a case, there is a further need for cleaning inner walls of the process chamber **502** or **602** with water or alcohol to remove inner-wall depositions that have absorbed oxygen or moisture, and for performing again evacuation, baking and idle discharge to restore the process chamber atmosphere to the original state. Such trouble restoration procedure would usually take two to three hours to a half day, causing a problem of enormous time and cost losses.

[**0022**] Accordingly, an object of the present invention is to solve these and other problems and provide a plasma processing apparatus for performing plasma processing on substrates or the like, the plasma processing apparatus being enabled to perform proper plasma processing even for substrates of special configurations to be used for experiments and development without requiring time and labor for substrate bonding onto another disc-shaped wafer or the like while reducing the occurrence of trouble related to the conveyance of the substrate within the plasma processing apparatus.

[**0023**] The present invention has the following constitutions in order to achieve the above object.

[**0024**] According to a first aspect of the present invention, there is provided a plasma processing apparatus for generating a plasma by applying electric power (by applying radio-frequency power or DC power) and performing plasma processing on a substrate (particularly, abnormally shaped substrate or the like), comprising:

[**0025**] a process chamber in which the plasma processing is performed on the substrate placed inside thereof;

[**0026**] a preliminary chamber (load lock chamber, or a preliminary chamber for preparation of the plasma processing; the chamber may be a vacuum preliminary chamber or preliminary exhaust chamber rather than a chamber to be evacuated) which is a chamber intervening between the process chamber and outside of the apparatus (a chamber interruptibly communicated with the process chamber by one communicating hole) and which has a lid portion for

interrupting the preliminary chamber from the outside of the apparatus by closing thereof and for allowing the substrate to be delivered between the outside of the apparatus and interior of the preliminary chamber by opening thereof;

[0027] an evacuator (pressure-reducing device or a first evacuator for evacuating interior of the process chamber to draw a vacuum and a second evacuator for exhausting the interior of the preliminary chamber to draw a vacuum) for evacuating (or pressure-reducing) each of interior of the process chamber and the interior of the preliminary chamber to draw a vacuum;

[0028] a reactant gas supply portion for supplying reactant gas into the process chamber;

[0029] a substrate electrode portion having a substrate placement surface on which the substrate is to be placed (directly without using any other substrate for use of carrying or the like), for performing temperature control of the placed substrate by heat transfer through the substrate placement surface during the plasma processing;

[0030] an electric power applying device for applying radio-frequency power or DC power as the electric power to a coil or an electrode provided in the process chamber; and

[0031] a substrate electrode moving device for moving the substrate electrode portion (with keeping the substrate placement surface in a horizontal position along one direction) forward and backward between a plasma processing position where the plasma processing is performed on the substrate placed on the substrate placement surface in the process chamber that has been evacuated by the evacuator and to which the reactant gas has been supplied by the reactant gas supply portion and in which a plasma has been generated by applying the electric power to the coil or electrode by the electric power applying device, and a substrate delivery position where the substrate is delivered through the opened lid portion between the outside of the apparatus and the substrate placement surface within the preliminary chamber.

[0032] According to a second aspect of the present invention, there is provided a plasma processing apparatus as defined in the first aspect, wherein the preliminary chamber is placed along a direction inclined with respect to a center axis of the process chamber; and

[0033] the substrate electrode moving device is operable to move the substrate electrode portion between the plasma processing position and the substrate delivery position along a move axis set along the inclined direction.

[0034] According to a third aspect of the present invention, there is provided a plasma processing apparatus as defined in the second aspect, wherein an angle of the inclination is any one within a range of 30 to 60 degrees.

[0035] According to a fourth aspect of the present invention, there is provided a plasma processing apparatus as defined in the first aspect, wherein the preliminary chamber is placed along a generally horizontal direction which is a direction generally perpendicular to a center axis of the process chamber; and

[0036] the substrate electrode moving device is operable to move the substrate electrode portion between the plasma processing position and the substrate delivery position along a move axis set along the generally horizontal direction.

[0037] According to a fifth aspect of the present invention, there is provided a plasma processing apparatus as defined in the first aspect, wherein the lid portion is placed so as to allow the substrate placement surface of the substrate electrode portion positioned at the substrate delivery position to be visually recognized from the outside of the apparatus, and allow the substrate to be placed onto the substrate placement surface directly (e.g., by operator's manual work) from the outside of the apparatus, in its opened state.

[0038] According to a sixth aspect of the present invention, there is provided a plasma-processing apparatus as defined in the first aspect, further comprising:

[0039] a communicating gate portion for making the process chamber and the preliminary chamber communicated with each other so as to allow the substrate electrode portion with the substrate placed thereon to pass through the communicating gate portion; and

[0040] a process chamber interruption part which is movable integrally with the substrate electrode portion and which, with the substrate electrode portion positioned to the plasma processing position, closes the communicating gate portion to interrupt the process chamber and the preliminary chamber from each other, and with the substrate electrode portion positioned to the substrate delivery position, opens the communicating gate portion to release the process chamber and the preliminary chamber from the interruption, thereby making the process chamber and the preliminary chamber communicated with each other.

[0041] According to a seventh aspect of the present invention, there is provided a plasma processing apparatus as defined in the fifth aspect, further comprising an interruption device having an openable/closable gate lid for closing the communicating gate portion to interrupt communication between the process chamber and the preliminary chamber, with the substrate electrode portion positioned to the substrate delivery position.

[0042] According to an eighth aspect of the present invention, there is provided a plasma processing apparatus as defined in the seventh aspect, further comprising:

[0043] at least two preliminary chambers communicated with the one process chamber;

[0044] at least two substrate electrode portions which are movable forward and backward between the substrate delivery position in each of the preliminary chambers and the plasma processing chamber in the process chamber (along one direction); and

[0045] at least two communicating gate portions which make the process chamber and each of the preliminary chambers communicated with each other, wherein

[0046] the substrate electrode moving device is operable to position one substrate electrode portion selected out of the substrate electrode portions to the plasma processing position and to position the other substrate electrode portion to the substrate delivery position, and

[0047] the interruption device is operable to close and interrupt the communicating gate that serves for communication between the process chamber in which the one substrate electrode portion is positioned and the preliminary chamber in which the other substrate electrode portion is positioned.

[0048] According to a ninth aspect of the present invention, there is provided a plasma processing apparatus as defined in the second aspect, further comprising a substrate electrode rotating device for rotating the substrate electrode portion about a rotational center that is given generally by the move axis of the substrate electrode portion by the substrate electrode moving device, wherein

[0049] the substrate placed on the substrate placement surface differs in placement posture (i.e., plasma processing is performed in these different processing postures) between its one placement posture at the substrate delivery position and its another processing posture at the plasma processing position.

[0050] According to a tenth aspect of the present invention, there is provided a plasma processing apparatus as defined in the first aspect, further comprising a substrate delivery device for performing delivery of the substrate between the substrate placement surface of the substrate electrode portion positioned at the substrate delivery position and the outside of the apparatus.

[0051] According to an eleventh aspect of the present invention, there is provided a plasma processing apparatus as defined in the first aspect, wherein holding of a placement position of the substrate to the substrate placement surface is fulfilled by an adhesive material which is interposed between the substrate and the substrate placement surface, and by which close contact between the substrate and the substrate placement surface is facilitated by the interior of the preliminary chamber being evacuated by the evacuator, and which allows heat transfer between the substrate and the substrate placement surface for the plasma processing.

[0052] According to a twelfth aspect of the present invention, there is provided a plasma processing apparatus as defined in the eleventh aspect, wherein the substrate electrode portion further comprises a heating device capable of heating the substrate placement surface, and

[0053] the heating device is, by heating the adhesive material, capable of aiding bonding, fixing and release of close contact between the substrate and the substrate placement surface by the adhesive material.

[0054] More specifically, there is provided a plasma processing apparatus as defined in the eleventh aspect, wherein the substrate electrode portion further comprises a heating device for performing temperature control of the substrate in the process chamber and heating the substrate placement surface,

[0055] the heating device is operable to:

[0056] for feeding the substrate in the preliminary chamber, heat the adhesive material through the substrate placement surface to melt or soften the adhesive material so that the substrate placed on the substrate placement surface and the substrate placement surface are brought into close contact with each other via the adhesive material;

[0057] for plasma processing of the substrate in the process chamber, perform solidification of the melted or softened adhesive material by lowering temperature of the heating, thereby fixing the close contact between the substrate and the substrate placement surface via the adhesive material and further fulfilling the temperature control of the substrate by heat transfer through the substrate placement surface and the adhesive material; and

[0058] for discharging of the substrate in the preliminary chamber, heat the adhesive material once again to melt or soften the solidified adhesive material, thereby aiding release of the fixing of the close contact between the substrate and the substrate placement surface by the adhesive material.

[0059] According to the first aspect of the present invention, since the substrate electrode portion is made reciprocatingly movable between the plasma processing position within the process chamber and the substrate delivery position within the preliminary chamber, the substrate fed at the substrate delivery position can be carried to the plasma processing position for the substrate along with the substrate electrode portion as the substrate is placed on the substrate placement surface of the substrate electrode portion. Conversely, the substrate that has been subjected to plasma processing at the plasma processing position can be carried to the substrate delivery position along with the substrate electrode portion. As a result of such carriage being enabled, for example, it becomes possible to feed the substrate as the substrate is placed on the substrate placement surface directly by operator's hand against the substrate electrode portion positioned at the substrate delivery position, and also to take out the placed substrate out of the apparatus by the operator's hand.

[0060] Further, by virtue of the provision of the lid portion that enables the delivery of the substrate between the substrate placement surface placed at the substrate delivery position in the preliminary chamber and the outside of the apparatus, the feed and discharge of the substrate can be achieved directly between the substrate placement surface and the outside of the apparatus.

[0061] Accordingly, for example, the substrate having characteristics of being thin and weak in its strength (e.g., compound semiconductor wafer etc.) can be carried without intervention of any carrier robot that would be employed in conventional plasma processing apparatuses, so that occurrence of carrying trouble such as drop of the wafer can be prevented, and moreover that various constraints on the configuration the substrate involved in the intervention of a carrier robot can be eliminated.

[0062] In particular, the push-up device, which would be necessary to scoop and carry the wafer placed on the substrate electrode portion in conventional plasma processing apparatuses, can be made unnecessary in the plasma processing apparatus of the this aspect. As a result of this, damage of the wafer due to the push-up pin on the substrate electrode as well as drop of the wafer, which would hitherto

occur as carrying trouble, can be prevented, so that reliable carriage of the substrate can be achieved.

[0063] Also, as to the issue that chiefly only disc-shaped wafers can be carried, which has been a constraint involved in the intervention of a carrier robot, since the substrate can be carried as it is placed directly on the substrate placement surface, it becomes implementable to carry even subdivided-disc substrates or abnormally shaped substrates or the like typified by compound semiconductor wafers, so that the above issue can be solved. In particular, such abnormally shaped substrates are in many cases used for experiment and development uses, there can be provided a plasma processing apparatus suitable for such experiment and development uses.

[0064] Also, since plasma processing for the abnormally shaped substrate can be carried out as it is placed directly on the substrate placement surface without being stuck onto, for example, a disc-shaped wafer or the like, the plasma processing can be performed without impairing thermal conductivity of the abnormally shaped substrate to the substrate electrode portion. Accordingly, there can be provided a plasma processing apparatus which is capable of performing plasma processing in which the substrate temperature is maintained at an optimum one with such special-configuration substrates and which is suited for experiment and development uses and small-quantity production use.

[0065] According to the second aspect of the present invention, in the plasma processing apparatus, the preliminary chamber is disposed along such a direction as to be inclined against the process chamber center axis, the substrate electrode portion being movable along the inclined direction, e.g., a direction inclined relative to a direction perpendicular to the substrate placement surface (i.e., inclined one direction) between the plasma processing position and the substrate delivery position, i.e., being "obliquely movable." By virtue of this, performing the move makes it possible to realize substantially "horizontal move" and "vertical move"-concurrently.

[0066] Thus, the substrate can be carried by "horizontal move" from the substrate delivery position within the preliminary chamber to the interior of the process chamber. Further, by "vertical move," the substrate to be subjected to plasma processing can be brought close to the coil or electrode of the process chamber, by which the substrate can be exposed to a strong plasma. Although some conventional apparatuses particularly in which only "horizontal move" is performed have had a problem that the substrate can only be carried to a position far from a plasma generation portion in the process chamber, the plasma processing apparatus as described above makes it implementable to provide an apparatus that meets two requirements at the same time, i.e., one requirement for substrate carriage and the other requirement that the substrate being exposed to a strong plasma.

[0067] Further, in the constitution in which the substrate electrode portion is moved along the inclined direction as shown above, a larger space can be ensured upward of the substrate placement surface, as compared with the case where only "horizontal move" is performed. As a result of this, not only substrates of smaller configurational heights such as disc-shaped wafers or the like but also substrates of higher configurational heights and fixing jigs for substrates can be placed on the substrate placement surface, so that plasma processing on workpieces of wider varieties of configurations can be realized.

[0068] According to the third aspect of the present invention, since the angle of the inclination is any one within a range of 30 to 60 degrees, it becomes implementable to effectively obtain the above individual working effects of realizing the "horizontal move" and the "vertical move."

[0069] According to the fourth aspect of the present invention, even in a case where the move axis of the substrate electrode portion by the substrate electrode moving device is set generally horizontal, there can be provided a plasma processing apparatus capable of obtaining the working effects by the first aspect.

[0070] According to the fifth aspect of the present invention, since the lid portion of the preliminary chamber is so placed that, in its opened state, the substrate placement surface of the substrate electrode portion positioned at the substrate delivery position can be visually recognized from the outside of the apparatus, the substrate placement surface can securely be viewed by opening the lid portion. For example, in a case where the preliminary chamber is disposed along the inclined direction, the lid portion can be provided at a side face of the preliminary chamber, which is above the substrate delivery position, in the preliminary chamber by making use of the inclination. In such a case, opening the lid portion makes it possible to reliably view the substrate placement surface from its upward. Accordingly, in the feeding operation or extraction operation by the placement of the substrate, a decision as to secure feed or reprocessing of the substrate or discharge operation of the processed substrate can be made while the state (placement state, plasma processing result, etc.) of the substrate is visually recognized. Such effects can be said to be suitable particularly for experiment and development uses in which abnormally shaped wafers or the like are more often used.

[0071] According to the sixth aspect of the present invention, by the provision of the process chamber interruption part which is movable integrally with the substrate electrode portion and which, with the substrate electrode portion positioned to the plasma processing position, closes the communicating gate portion to interrupt the process chamber and the preliminary chamber from each other, and with the substrate electrode portion positioned to the substrate delivery position, opens the communicating gate portion to release the process chamber and the preliminary chamber from the interruption, it becomes possible to perform the interruption (i.e., sealing) of the process chamber and the releasing (release of the sealing) operation by the carrying operation of the substrate. Accordingly, the plasma processing apparatus can be further simplified in construction, and gas and discharge within the process chamber never runs about into the preliminary chamber, and reliable plasma processing in which occurrence frequency of faults or the like is reduced can be made implementable.

[0072] According to the seventh aspect of the present invention, there is further provided an interruption device which, with the substrate electrode portion positioned to the substrate processing position, interrupts the process chamber and the preliminary chamber from each other. As a result of this, even in the case where the preliminary chamber is opened for the feed or discharge of the substrate, the process chamber can be maintained in a sealed state. Therefore, the

interior of the process chamber can normally be maintained at an atmosphere (e.g., a state of pressure, temperature, wall-surface deposition, etc.) suitable for plasma processing, so that efficient processing can be achieved when plasma processing is performed continuously on a plurality of the substrates or the like.

[0073] According to the eighth aspect of the present invention, the preliminary chamber, the substrate electrode portion and the communicating gate portion are provided each at least two for one process chamber. Therefore, in the state that one substrate electrode portion is positioned at the plasma processing position while the other substrate electrode portion is positioned at the substrate delivery position, when the communicating gate portion is closed to make the process chamber and the preliminary chambers interrupted from each other, it is implementable that while plasma processing is performed on the substrate placed on the one substrate electrode portion, substrate delivery or the like can be performed on the other substrate electrode portion. Thus, it is possible to provide a plasma processing apparatus capable of efficient plasma processing.

[0074] According to the ninth aspect of the present invention, by the further provision of a substrate electrode rotating device for rotating the substrate electrode portion about a rotational center that is given generally by the move axis of the substrate electrode portion, it becomes possible that, with respect to the substrate placed on the substrate placement surface, its placement posture at the substrate delivery position and its processing posture at the plasma processing position can be made different from each other.

[0075] Thus, for example, in a plasma processing apparatus in which the move axis of the substrate electrode portion by the substrate electrode moving device is inclined at an inclination angle of 45 degrees with respect to the process chamber center axis, the substrate placement surface can be postured generally horizontal at the substrate delivery position of the preliminary chamber, so that the substrate can securely be placed on the substrate placement surface. Also, by holding the placement position of the substrate placed as shown above with an electrostatic chuck or the like as an example, and further by rotating the substrate electrode portion by 180 degrees about the move axis with the substrate electrode moving device while positioning the substrate electrode portion to the plasma processing position with the substrate electrode moving device, the substrate placement surface can be disposed along the generally vertical direction in the process chamber, and plasma processing can be carried out while the substrate is held in the dispositional posture. Thus, deposition of dust or the like onto the surface of the substrate can be reduced, so that an etching surface or film-deposited surface of high quality can be formed on the surface of the substrate by the plasma processing.

[0076] According to the tenth aspect of the present invention, by the further provision of a substrate delivery device for performing delivery of the substrate between the substrate placement surface of the substrate electrode portion positioned at the substrate delivery position and the outside of the apparatus, the delivery of the substrate between the substrate placement surface and the outside of the apparatus can automatically be carried out without doing manual work by an operator or the like, thus making unmanned continuous processing practicable.

[0077] According to the eleventh aspect of the present invention, by the placement of the substrate on the substrate placement surface with intervention of the adhesive material, it becomes possible that by evacuating the interior of the preliminary chamber after the placement, the adhesive material and the substrate as well as the substrate placement surface can be brought into close contact with each other while air bubbles contained in the heat-transferable adhesive material are removed. As a result, the placement position of the substrate onto the substrate placement surface can securely be held, occurrence of deterioration of the heat transferability between the substrate and the substrate placement surface due to remaining of a large amount of air bubbles can be prevented, so that heat transferability necessary for plasma processing can be ensured. Accordingly, it is possible to provide a plasma processing apparatus capable of reliable, efficient plasma processing.

[0078] According to the twelfth aspect of the present invention, since the substrate electrode portion further comprises a heating device which is capable of heating the substrate placement surface. Thus, by freely performing heating or cooling (cooling by lowering the heating temperature) of the adhesive material, the work of bonding, fixing and releasing of close contact between the substrate and the substrate placement surface by the heat-transferable adhesive material can be made easier to do, for example, by melting or softening or resolidifying of adhesive material or the like.

BRIEF DESCRIPTION OF THE DRAWINGS

[0079] These and other aspects and features of the present invention will become clear from the following description taken in conjunction with the preferred embodiments thereof with reference to the accompanying drawings, in which:

[0080] **FIG. 1** is a schematic view of a plasma processing apparatus according to a first embodiment of the present invention;

[0081] **FIG. 2** is a schematic view showing a moving state of a lower electrode in the plasma processing apparatus of **FIG. 1**;

[0082] **FIG. 3** is an enlarged view of a process chamber and the lower electrode in the plasma processing apparatus of **FIG. 1**;

[0083] **FIG. 4** is a sectional view taken along the line C-C in the plasma processing apparatus of **FIG. 2**, showing the construction of a gate lid opening/closing device;

[0084] **FIG. 5** is a schematic perspective view showing the way in which the wafer placement position onto the placement surface of the lower electrode;

[0085] **FIG. 6** is a schematic view of a plasma processing apparatus according to a second embodiment of the present invention;

[0086] **FIG. 7** is a schematic view of a plasma processing apparatus according to a third embodiment of the present invention;

[0087] **FIG. 8** is a sectional view taken along the line D-O-D in the plasma processing apparatus of **FIG. 7**;

[0088] **FIG. 9** is a schematic view of a plasma processing apparatus according to a fourth embodiment of the present invention;

[0089] **FIG. 10** is a schematic view of a plasma processing apparatus according to a modification of the first embodiment;

[0090] **FIG. 11** is a schematic view of a conventional plasma processing apparatus;

[0091] **FIG. 12** is a schematic view of a plasma processing apparatus according to another conventional example;

[0092] **FIG. 13** is a schematic sectional view of the lower electrode according to the modification of the first embodiment; and

[0093] **FIG. 14** is a schematic sectional view showing a state of trying to place the wafer on the placement surface of the lower electrode of **FIG. 13**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0094] Before the description of the present invention proceeds, it is to be noted that like parts are designated by like reference numerals throughout the accompanying drawings.

[0095] Hereinbelow, embodiments of the present invention are described in detail with reference to the accompanying drawings.

First Embodiment

[0096] (Construction of Plasma Processing Apparatus)

[0097] A schematic view (partial sectional view) showing a schematic construction of a plasma processing apparatus **100** according to a first embodiment of the present invention is shown in **FIG. 1**.

[0098] As shown in **FIG. 1**, the plasma processing apparatus **100** has a process chamber **2** which is a sealable chamber and in which a wafer **1**, an example of substrates, is to be set, thereby making the wafer **1** subjected to specified plasma processing, and a preliminary chamber **3** (vacuum preliminary chamber or preliminary evacuation chamber) which is interposed between the process chamber **2** and the outside of the plasma processing apparatus **100** and which is a sealable chamber and further which is interruptibly communicated with the process chamber **2** by, for example, one communicating hole.

[0099] The process chamber **2** is defined inside by a process chamber vessel **5** having two planar portions **5*a*** and **5*b*** generally perpendicularly connected to each other in a V shape, a cylinder and a conical-shaped bottom, and a bell jar **12** which is so formed as to cover the entire top portion of the process chamber vessel **5** and which has a top plate portion of a gently curved surface shape. The bell jar **12** can be formed of a dielectric such as quartz or ceramics.

[0100] A lower electrode **4** which is an example of a substrate electrode portion having at its upper surface a placement surface **4*a*** on which the wafer **1** can be placed can be positioned at a plasma processing position A, which is a position of a generally center portion in the process chamber **2**. Also, a turbo-pump **17** for evacuating the internal space of the process chamber **2** to attain a vacuum while maintaining the chamber at a desired pressure is provided in the process chamber **2**. This turbo-pump **17** is placed outside one planar portion **5*a*** (on the left side in the figure) out of the two planar portions **5*a*** and **5*b***, which form the process chamber vessel **5**, so as to communicate with the internal space of the process chamber **2** via a pressure control valve **18** (for example, control valve made by VAT Vakuumventile AG., Switzerland). Also, a first rotary pump **16** is connected in series to the turbo-pump **17**, making it implementable to evacuate (or reduce in pressure) the interior of the process chamber **2**. It is noted that the turbo-pump **17** and the first rotary pump **16** are an example of a first evacuator in the first embodiment. The process chamber **2** has a gas inlet **14**, which is an example of the reactant gas supply portion for supplying reactant gas to the internal space of the process chamber **2**. In addition, a reactant gas supply pipe and a nitrogen gas supply pipe, on each of which an opening/closing valve is provided, is connected to the gas inlet **14** so that reactant gas (process gas) or nitrogen gas (N_2) can be selectively supplied.

[0101] Further, a coil **6**, which is an example of a multiply-wound coil, is placed outside and around the bell jar **12** in the process chamber **2**, and radio-frequency power is applied to the coil **6** through a radio-frequency power supply **8** and a matcher **10**, which are an example of an electric power applying device connected to the coil **6**, thus making it possible to excite a plasma within the process chamber **2** via the bell jar **12**. For instance, the radio-frequency power supply **8** is enabled to apply a radio-frequency power having a frequency of 13.56 MHz and a power of 1 kW. In addition, other than such a case where the coil **6** is provided, it is also possible that with an electrode provided on an outside periphery or inside of the bell jar **12**, a radio-frequency or DC power is applied to the electrode by an electric power applying device.

[0102] As shown in **FIG. 1**, a communicating gate **28** is formed at the other planar portion **5*b*** (on the right side in the figure) in the process chamber vessel **5**, the communicating gate **28** being an example of a communicating gate portion which is one communicating hole (opening) that communicates the process chamber **2** and the preliminary chamber **3** with each other. The preliminary chamber **3** is formed of a preliminary chamber vessel **7** having a generally hollowed prismatic shape, and the communicating gate **28** is placed at an upper portion of the prismatic shape. As a result of such a placement of the preliminary chamber **3**, the preliminary chamber **3** is placed in a state that a preliminary chamber center axis Q, which is the center axis of the prismatic shape of the preliminary chamber **3**, is inclined by an inclination angle θ with respect to a process chamber center axis P. It is noted that this inclination angle θ is preferably set to, for example, an angle within a range of about 30 to 60 degrees, and more preferably, an angle of about 45 degrees.

[0103] The lower electrode **4** is enabled to move with its placement surface **4*a*** maintained generally horizontal between the plasma processing position A and a wafer delivery position B which is near a generally center of the preliminary chamber **3** and shifted along a preliminary chamber center axis B from the plasma processing position A and which an example of a substrate delivery position where delivery of the wafer **1** is done between the preliminary chamber **3** and outside of the apparatus. Also, a wafer delivery gate **23**, which is an opening that makes it possible to deliver the wafer **1** between the placement surface **4*a*** located at the wafer delivery position B and the outside of the apparatus, is formed at an upper portion, as viewed in the

figure, of a side face of the inclined prismatic shape of the preliminary chamber **3**, and further a lid **22**, which is an example of a lid portion that can open and close the wafer delivery gate **23**. Closing this lid **22** allows the internal space of the preliminary chamber **3** to be sealed, while opening the lid **22** allows the wafer **1** to be fed and discharged through the wafer delivery gate **23**. This lid **22** is formed of, for example, an acrylic resin or the like, which is a transparent material, and the lid **22**, when in a closed state, allows the placement surface **4***a* located at the wafer delivery position B to be visually recognized from the outside of the apparatus through the lid **22**, that is, the lid **22** as a whole acts as an example of visualization window. This lid **22**, instead of being formed wholly of the transparent material, may also be formed partly of the transparent material in a window state.

[0104] The preliminary chamber **3** is further equipped with a slide shaft **32** which is a shaft portion having the lower electrode **4** set at its upper end portion and which slidingly moves along the preliminary chamber center axis Q (which is an example of a move axis) so that the placement surface **4***a* can be moved between the plasma processing position A and the wafer delivery position B, and an air cylinder **34** which performs the above move of the slide shaft **32**. It is noted that, in the first embodiment, the slide shaft **32** and the air cylinder **34** are an example of a substrate electrode moving device. Also, bellows **36** are set on outer peripheries of the slide shaft **32** within the preliminary chamber **3**. The positioning of a move position of the slide shaft **32** to the plasma processing position A and the wafer delivery position B by the air cylinder **34** can be done mechanically by using, for example, a stopper or the like. Furthermore, in order to relieve shocks that occur when the moved slide shaft **32** is stopped at the plasma processing position A or the wafer delivery position B, it is preferable that, for example, a shock absorber is provided at the slide shaft **32**.

[0105] At a connecting portion between the lower electrode **4** and the slide shaft **32** is formed an interruption part **30** (which is an example of a process chamber interruption part) which is an example of a flange-shaped flange portion so formed as to protrude from the outer periphery of the lower electrode **4**. As a result of this, when the placement surface **4***a* is positioned to the plasma processing position A, the process chamber **2** can be sealed by making the peripheral portion of the interruption part **30** brought into contact with the periphery of the communicating gate **28** (i.e., interrupting the process chamber **2** and the preliminary chamber **3** from each other), while the contact between the peripheral portion of the interruption part **30** and the periphery of the communicating gate **28** can be released so that the process chamber **2** is released from the sealing (i.e., the interruption is released) by making the placement surface **4***a* moved toward the wafer delivery position B. In addition, in order to ensure such a function, the outer periphery of the lower electrode **4** is formed so as to be smaller than the opening portion of the communicating gate **28** so that, the lower electrode **4** is allowed to pass through without making contact with the communicating gate **28**, while the outer periphery of the interruption part **30** is formed so as to be larger than the opening portion of the communicating gate **28** so that the peripheral portion of the interruption part **30** is securely brought into contact with the periphery of the communicating gate **28**.

[0106] In the preliminary chamber **3** is provided a second rotary pump **20** which is an example of a second evacuator and which is capable of independently evacuating (or pressure-reducing) the internal space of the preliminary chamber **3** to maintain it at a specified pressure.

[0107] Now a schematic view showing a state of the above-described move of the lower electrode **4** in the plasma processing apparatus **100** is shown in **FIG. 2**.

[0108] As shown in **FIG. 2**, the placement surface **4***a* of the lower electrode **4** is set movable between the plasma processing position A (shown by broken line) within the process chamber **2** and the wafer delivery position B (shown by solid line) within the preliminary chamber **3**. In the state that the placement surface **4***a* is located at the wafer delivery position B, the setting of the wafer delivery position B is so determined that the whole lower electrode **4** can be accommodated in the preliminary chamber **3**.

[0109] Also, as shown in **FIG. 2**, in the state that the placement surface **4***a* of the lower electrode **4** is located at the wafer delivery position B, the communicating gate **28**, which is a communicating portion between the process chamber **2** and the preliminary chamber **3**, is set to an opened state. In order to make the process chamber **2** sealed even in such a state, the preliminary chamber **3** is equipped with a gate lid **24** that can open and close the communicating gate **28**, and a gate lid opening/closing device **26** that performs the opening/closing operation of this gate lid **24**. In this state, the process chamber **2** can be sealed by interrupting the process chamber **2** and the preliminary chamber **3** from each other, which is done by closing the communicating gate **28** by the gate lid **24**. By sealing the process chamber **2** by using the gate lid **24** like this, for example, as shown in **FIG. 2**, even in a case where the preliminary chamber **3** is opened and closed to feed and discharge the wafer **1**, the interior of the process chamber **2** can be maintained in a sealed state without being exposed to the atmosphere of the outside of the apparatus. It is noted that the gate lid **24** and the gate lid opening/closing device **26** is an example of the interruption device in the first embodiment.

[0110] Now an enlarged schematic view of the process chamber **2** and the lower electrode **4** is shown in **FIG. 3**, and the construction of the lower electrode **4** and the like is explained in more detail.

[0111] As shown in **FIG. 3**, an ESC layer (Electro Static Chuck layer (or electrode)) **41**, which is an electrode for electrostatically chucking the wafer **1** placed on the placement surface **4***a* in such a manner that the electrostatic chuck can be released, and a radio-frequency layer **42** that is an electrode which is placed below the ESC layer **41** and to which a radio-frequency power is applied, are provided so as to be contained inside the lower electrode **4**. The ESC layer is formed in divisions on the right and left sides of the placement surface **4***a* as viewed in the figure, and one of those divisions is connected to an electrostatic chuck positive pole **48** and the other is connected to an electrostatic chuck negative pole **47** through electric wiring set inside the hollow slide shaft **32**. Further, the radio-frequency layer **42** is connected to a bias radio-frequency power supply **49** through electric wiring set inside the slide shaft **32**. By the bias radio-frequency power supply **49**, for example, a radio-frequency power having a frequency of 13.56 MHz and an

electric power of 200 W is applied to the radio-frequency layer **42** for the plasma processing on the wafer **1**.

[**0112**] Further below the radio-frequency layer **42** in the lower electrode **4** is placed a water jacket **43** for heating or cooling the lower electrode **4**. A plurality of cooling/heating medium flow passages **4**-**4***a* through which a cooling/heating medium fluid is permitted to flow are formed inside the water jacket **43**, and a plurality of cooling/heating pipes **44** for feeding or discharging the cooling/heating medium fluid are set inside the slide shaft **32** so as to permit the cooling/heating medium fluid to pass through these cooling/heating medium flow passages **44***a*.

[**0113**] Also, between the placement surface **4***a* and the lower surface of the wafer **1** placed on the placement surface **4***a*, a heat-transfer-gas supply hole **45***a* for supplying a heat transfer gas is formed in proximity to a generally center of the placement surface **4***a*, and this heat-transfer-gas supply hole **45***a* is connected to a heat-transfer-gas supply pipe **45** set inside the slide shaft **32** so that heat transfer gas is suppliable. By the heat-transfer-gas supply hole **45***a* being formed in the placement surface **4***a* like this, it becomes possible to fill the heat transfer gas to minute gaps present between the lower surface of the wafer **1** and the placement surface **4***a* in the internal atmosphere of the process chamber **2** that is to be evacuated during plasma processing, thus making it possible to perform necessary heating or cooling with heat conduction from lower electrode **4** to the wafer **1** via the heat transfer gas. As this heat transfer gas, for example, a helium gas of an about 1000 Pa pressure (about 1/100 atmospheric pressure) is used.

[**0114**] The lower electrode **4** is supported by a generally cylindrical-shaped electrode support portion **46**, and the interruption part **30** is formed at a lower portion of the electrode support portion **46**. Further, by the slide shaft **32** being moved forward and backward, as shown in **FIG. 3**, a specified space which is free from contact with any other apparatus constituent portion is normally secured upward of the placement surface **4***a* by virtue of the inclination between the process chamber center axis P and the preliminary chamber center axis Q with the inclination angle θ even in the case where the lower electrode **4** passes through the communicating gate **28**. Therefore, for example, it is also possible to set a workpiece **1***a* (or substrate fitting jig) having a relatively high formation height instead of the planar-shaped wafer **1** as shown in **FIG. 3**.

[**0115**] In this connection, also, a sectional view taken along the line C-C in **FIG. 2** is shown in **FIG. 4** as a view showing the construction of the gate lid opening/closing device **26** and the gate lid **24** in the plasma processing apparatus **100**. It is noted that **FIG. 4** shows a state that the lid **22** of the preliminary chamber **3** closes the wafer delivery gate **23**.

[**0116**] As shown in **FIG. 4**, the gate lid **24** is fixed to the other end of a lid support portion **29** which is rotatably fixed at the rotational center of the gate lid opening/closing device **26**, and the gate lid **24** can be rotated forward or reverse about the rotational center by rotationally moving the lid support portion **29** forward or reverse by the gate lid opening/closing device **26**. As a result of this rotational move, the gate lid **24** can be rotationally moved between a closure position R, which is a position where the communicating gate **28** can be closed, and an open position S, which is a position where the communicating gate **28** can be opened. Also, in addition to the function of driving the rotation, the gate lid opening/closing device **26** further has a function of moving the lid support portion back and forth along the preliminary chamber center axis Q. By virtue of this, the gate lid **24** positioned at the closure position R can be moved toward the communicating gate **28** so as to be pressed thereagainst, by which the process chamber **2** can be sealed. Such back-and-forth move along the preliminary chamber center axis Q can be achieved by using, for example, a cylinder or other like mechanism, the range of the back-and-forth move being implemented by limit switch detection. More specifically, in this first embodiment, a pneumatic rotation-expansion actuator as an example is used as the gate lid opening/closing device **26**. Also, as shown in **FIG. 4**, a lid housing chamber **25** which can house the gate lid **24** located at the open position S is formed in the preliminary chamber **3**.

[**0117**] In addition, as shown in each of FIGS. **1** to **4**, in the plasma processing apparatus **100**, seal members are provided at necessary places in order to ensure the hermeticity of the process chamber **2** and the hermeticity of the preliminary chamber **3**. Although not indicated by reference numerals in the figures, portions expressed by black circle graphics correspond to the seal members. For instance, the seal members are provided at a connecting portion between the planar portion **5***a* of the process chamber **2** and the control valve **18**, a contact portion between the planar portion **5***b* and the interruption part **30** or gate lid **24**, and further a contact portion between the wafer delivery gate **23** and the lid **22** in the preliminary chamber **3**, or the like.

[**0118**] Also, as shown in **FIG. 2**, the wafer delivery gate **23** in the preliminary chamber **3** is formed, for example, so as to ensure enough size for an operator to carry the wafer **1** into the preliminary chamber **3** with a pair of tweezers and place the wafer **1** securely on the placement surface **4***a*.

[**0119**] Further, in the plasma processing apparatus **100**, the lower electrode **4** is provided so as to be attachable to and removable from the slide shaft **32**, and the case may be that different kinds of lower electrodes **4** are provided so as to be replaceable. In such a case, with respect to wafers **1** or the like of various configurations, a lower electrode **4** suited for each kind is selected and mounted on the slide shaft **32** for execution of plasma processing. In addition, the wafer delivery gate **23** in the preliminary chamber **3** is formed to such a size that replacement work by attachment and removal of the lower electrode **4** can be carried out.

[**0120**] (Plasma Processing Operation)

[**0121**] Next, with the plasma processing apparatus **100** having the above constitution, described below is plasma processing operation, which is a series of operations including the steps of feeding the wafer **1** and performing plasma processing, and then taking out the processed wafer **1** from the plasma processing apparatus **100**.

[**0122**] First, as shown in **FIG. 2**, in the plasma processing apparatus **100**, the placement surface **4***a* of the lower electrode **4** is positioned at the wafer delivery position B, and the gate lid **24** is positioned at the closure position R so that the process chamber **2** is sealed. In such a state, the lid **22** of the preliminary chamber **3** is opened and then the wafer **1** held by the operator with use of a wafer holding means such as

tweezers is carried into the preliminary chamber **3** through the wafer delivery gate **23**, and placed on the placement surface **4***a*.

[**0123**] Meanwhile, in this case, in the process chamber **2** in the sealed state, the turbo-pump **17** and the first rotary pump **16** are driven so that the pressure control valve **18** is opened, by which the evacuation within the process chamber **2** is started (otherwise, the case may be that the evacuation has already been started with the process chamber **2** maintained at a vacuum).

[**0124**] Thereafter, with the wafer **1** placed on the placement surface **4***a*, a specified voltage is applied to the ESC layer shown in **FIG. 3**, by which the wafer **1** in the placed state is electrostatically chucked on the placement surface **4***a*. When the operator has confirmed through the wafer delivery gate **23** that the wafer **1** has been placed securely on the placement surface **4***a* by this electrostatic chuck, the lid **22** is closed, by which the preliminary chamber **3** is sealed.

[**0125**] After the sealing of the preliminary chamber **3**, the second rotary pump **20** is driven so that the evacuation in the preliminary chamber **3** is started. When the interior of the preliminary chamber **3** has come to a specified pressure or lower by this evacuation, the gate lid **24** is moved to the open position S by the gate lid opening/closing device **26**, by which the process chamber **2** and the preliminary chamber **3** are communicated with each other.

[**0126**] Along with this, as shown in **FIG. 1**, the slide shaft **32** is moved along the preliminary chamber center axis Q by the air cylinder **34**, by which the placement surface **4***a* with the wafer 1 placed thereon is moved so as to be positioned at the plasma processing position A. By the placement surface **4***a* being moved in this way, the peripheral portion of the interruption part **30** and the peripheral portion of the communicating gate **28** are brought into contact with each other, thus making the process chamber **2** put into a sealed state again.

[**0127**] Thereafter, in the process chamber **2**, a specified reactant gas (process gas) is supplied through the gas inlet **14**, and moreover the pressure control valve **18** operates to maintain the interior of the process chamber **2** at a specified pressure. After that, a specified radio-frequency power is applied to the radio-frequency layer **42** of the lower electrode **4**, while a specified radio-frequency power is applied also to the coil **6**. When this occurs, or since before this, the cooling/heating medium fluid is passed to the water jacket **43** of the lower electrode **4**, by which the placement surface **4***a* of the lower electrode **4** is maintained at a specified temperature. Also, the heat transfer gas is supplied to the minute gaps between the lower surface of the wafer **1** and the placement surface **4***a* through the heat-transfer-gas supply hole **45***a*. Upon attainment of such a state, the wafer **1** is subjected to plasma processing.

[**0128**] Thereafter, after a specified time elapse, the supply of the reactant gas through the gas inlet **14** is stopped, and the application of the radio-frequency power to the coil **6** and the application of the radio-frequency power to the radio-frequency layer **42** are stopped, where the plasma processing is terminated. Further, the pressure control valve **18** is opened, so that the interior of the process chamber **2** comes to a high vacuum. After that, the slide shaft **32** is moved down along the preliminary chamber center axis Q by the air cylinder **34**, so that the placement surface **4***a* on which the plasma-processed wafer **1** is placed is positioned to the wafer delivery position B. Also, this move of the slide shaft **32** causes the process chamber **2** to be released from sealing, so that the process chamber **2** and the preliminary chamber **3** are communicated with each other.

[**0129**] After that, the gate lid **24** is moved to the closure position R by the gate lid opening/closing device **26**, and the communicating gate **28** is closed by the gate lid **24**, by which the process chamber **2** is put into a sealed state again. Thus, by the process chamber **2** being brought into a sealed state again even after the plasma processing, the interior of the process chamber **2** can be maintained at an atmospheric state (e.g., a state of temperature, pressure, wall-surface deposition, etc.) necessary for plasma processing, so that uniformization of plasma processing for a next fed wafer **1** as well as reduction in the time required to start the processing can be achieved.

[**0130**] After the sealing of the process chamber **2**, as shown in **FIG. 2**, in the preliminary chamber **3** interrupted from the process chamber **2**, the valve on the pipe of the second rotary pump **20** is closed, making the vacuum state broken, by which the interior of the preliminary chamber **3** is set to an atmospheric pressure. In addition, for example, such breakage of a vacuum state can be achieved by supplying nitrogen gas into the preliminary chamber **3** by opening the opening/closing valve on a nitrogen-gas supply pipe which is connected so that nitrogen gas (N_2) can be supplied to the interior of the preliminary chamber **3**. Thereafter, as the lid **22** is opened by the operator, the electrostatic chuck onto the placement surface **4***a* is released and, with the end portion of the wafer **1** held by using tweezers or the like, the plasma-processed wafer **1** is discharged to the outside of the plasma processing apparatus **100**.

[**0131**] Then, in the case where a next wafer **1** is to be subjected to plasma processing, the next wafer **1** is fed to the placement surface **4***a* of the lower electrode **4** through the wafer delivery gate **23**, where the plasma processing on the next wafer **1** can be performed by performing the above-described individual operations one after another.

[**0132**] In addition, the description of the above operational procedure has been done on a case where after the plasma processing has been performed, the placement surface **4***a* is moved to the wafer delivery position B so that the interior of the preliminary chamber **3** is brought to an atmospheric pressure state and the wafer **1** is taken out by the opening of the lid **22**. However, instead of such a case, the case may be another where after the placement surface **4***a* has been moved to the wafer delivery position B, a plasma processing state on the wafer **1**, is visually confirmed from the outside of the apparatus through the lid **22**, while the preliminary chamber **3** is kept evacuated, and then, as required, the placement surface **4***a* is moved again to the plasma processing position A, where the plasma processing is carried out. This is because, in particular, it may be necessary to confirm the plasma processing state during the plasma processing for experiment and development uses.

[**0133**] Further, the above description has been made on a case where the operator performs the feed and discharge of the wafer **1** is done by manual work against the placement surface **4***a* located at the wafer delivery position B in the

plasma processing apparatus **100**. However, the first embodiment is not limited to such cases only. For instance, instead of such a case, as shown in **FIG. 10**, automatic feed work and housing work of the wafer **1** can be performed by providing a transfer robot **90**, which is an example of the substrate delivery device, a wafer cassette **91** in which a plurality of wafers **1** are extractably housed, and a cassette lifter **92** which makes it possible to extract a desired wafer **1** by the transfer robot **90** by moving up and down the wafer cassette **91**. In addition, in such a case, the lid **22** of the preliminary chamber **3** is preferably given by adopting a slide type one in order to prevent by interference with by transfer robot **90**. Further, it is also possible that by preliminary chamber **3** is enlarged so as to allow the transfer robot **90**, the wafer cassette **91** and the cassette lifter **92** to be housed inside the enlarged preliminary chamber **3**, where the feed and housing of the wafers **1** may be automatically performed while the preliminary chamber **3** is maintained at a vacuum.

[0134] (Method of Holding the Placement Position of Wafer)

[0135] Next, the method of holding the placement position of the wafer **1** onto the placement surface **4***a* of the lower electrode **4** in the plasma processing apparatus **100** is explained as its several concrete examples.

[0136] First, a first holding method of the placement position is a placement method of the wafer **1** by electrostatic chuck that has been used in the description of the foregoing plasma processing operation. This is a method in which the wafer **1** is electrostatically held by a specified voltage being applied to the ESC layer **41** contained in the lower electrode **4** as shown in **FIG. 3**. An electrostatic chuck can be performed by such a voltage application, and the electrostatic chuck can be released by releasing the voltage application.

[0137] Next, a second holding method of the placement position is one in which with the wafer **1** or the placement surface **4***a* preparatorily supplied with an adhesive agent such as wax or tackiness agent, the wafer **1** is stuck to the placement surface **4***a* via the adhesive or the like, thereby holding the placement position of the wafer **1**.

[0138] Here is explained the structure of a lower electrode **104**, which is an example of the substrate electrode portion suited for this second holding method of the placement position as described above, with reference to a schematic sectional view shown in **FIG. 13**. It is noted that this lower electrode **104** is a modification example of the lower electrode **4** shown in **FIG. 3**, and its components similar in constitution to those shown in **FIG. 3** are designated by like reference numerals for an easier understanding of the following explanation. Also, the lower electrode **104** differs in constitution from the lower electrode **4** shown in **FIG. 3** in that the lower electrode **104** has, below its placement surface **104***a*, a heater electrode layer **151** which is an example of the heating device, the rest of constitution being similar to that of the lower electrode **4**.

[0139] As shown in **FIG. 13**, an ESC layer **41** and a radio-frequency layer **42** are provided and built-in below the placement surface **104***a* of the lower electrode **104**, and a water jacket **43** is provided further below those. A heater electrode layer **151** of high resistance is provided between those radio-frequency layer **42** and water jacket **43**, and this heater electrode layer **151** is connected to an AC power supply **152** (or DC power supply) through electric wiring set inside the slide shaft **32**. As a result of this, by electric power added to the heater electrode layer **151** from the AC power supply **152** through the electric wiring, the placement surface **104***a* can be heated by this heater electrode layer **151**. Also, by controlling the amount of electric power applied to the heater electrode layer **151**, the heating temperature of the placement surface **104***a* can be maintained at an arbitrary condition.

[0140] The lower electrode **104** having such a constitution is positioned to the wafer delivery position B as shown in **FIG. 14**, and the lid **22** is opened, where the wafer **1** can be placed on the placement surface **104***a* of the lower electrode **104** by the operator's manual work or the like. In this placement, in **FIG. 14**, by applying electric power to the heater electrode layer **151**, the placement surface **104***a* is preparatorily heated to a specified temperature (e.g., a temperature of about 100 to 150° C.), in which state a wax **150** which is an example of adhesive material is fed and applied onto the heated placement surface **104***a* as shown in the figure.

[0141] It is noted here that the term, "adhesive material," refers to an adhesive material which has heat transferability and which has both a function as a heat transfer member that performs necessary heat transfer between the placement surface **104***a* of the substrate electrode portion **104** and the wafer **1**, and a function as an adhesive (or temporary adhesive agent) for holding the placement position of the wafer **1** to the placement surface **104***a* in a releasable fashion. Also, the term, "heat transfer," refers to heat transfer that is necessary to perform plasma processing on the wafer **1**, the heat transfer being necessary to control the temperature of the wafer **1** to a desired temperature by controlling the temperature of the placement surface **104***a*. Such an adhesive material may be given by using, for example, thermoplastic adhesives, waxes, tackiness agents, heat transfer greases (e.g., one in which alumina powder or the like is mixed with an oil that is less evaporable in a vacuum), a heat transfer sheet (e.g., one in which alumina powder, silver powder or the like is mixed with a soft resin), a vacuum grease that is less evaporable in a vacuum, and the like.

[0142] Thereafter, as shown in **FIG. 14**, the wafer **1** is placed onto the placement surface **104***a* with the wax **150** interposed therebetween. Being heated through the placement surface **104***a*, the wax **150** can be maintained in dissolved (or softened) state, so that the adhesion between the placement surface **104***a* and the wax **150** and between the wafer **1** and the wax **150** can be made better, compared with the case where the heating is not done.

[0143] Further thereafter, with the lid **22** closed, the preliminary chamber **3** is evacuated. With this evacuation, air bubbles present in the wax **150** can be reduced, so that the adhesion between the wafer **1** and the placement surface **104***a* and the wax **150** can be made better. Furthermore, since air bubbles are removed as shown above, the wax **150** can be enhanced in its heat transfer performance, so that the wafer **1** can be improved in temperature controllability.

[0144] After that, as shown in **FIG. 13**, as the lower electrode **104** is positioned to the plasma processing position A, the temperature of the heater electrode layer **151** is

lowered as an example, by which the placement surface **104***a* is controlled to an optimum temperature necessary for plasma processing. This temperature control may also be implemented in a case where a flow of a cooling medium or heating medium through the cooling/heating medium flow passages **44***a* or the like is done in combination. Further, such temperature control can be carried out in a state of successful controllability by virtue of the aforementioned enhanced heat transfer performance of the wax **150**. Like this, since the plasma processing is carried out in a state that the wafer **1** is controlled to a temperature suited for plasma processing through the placement surface **104***a* and the wax **150**, a successful plasma processing can be achieved.

[**0145**] After the plasma processing is ended, as the lower electrode **104** is positioned to the wafer delivery position B, the wax **150** is heated through the placement surface **104***a* by the heater electrode layer **151**. As a result of this, the solidified wax **150** can be dissolved (or softened), so that the wafer **1** can be taken out with more successful separability from the wax **150**.

[**0146**] Further, the holding of the placement position of the wafer **1** onto the placement surface **104***a* can be released, that is, the wafer **1** can be separated, by holding and picking up the placed wafer **1** at its end portion or the like with tweezers or other holding means. That is, as the wax **150**, one which allows the wafer **1** or the like to be easily released from its stuck state (i.e., released without breakage of the wafer **1**) by applying external force to the wafer **1** or the like in the aforementioned molten state (or aforementioned softened state) of the wax.

[**0147**] Such a method is suitable for the placement of wafers **1** which cannot be electrostatically chucked or wafers **1** which should be kept from any electrical effects due to the electrostatic chuck. For example, the method is suitable for performing the process of substrates which are formed of a material that inhibits the electrostatic chuck from exerting its action, such as sapphire. Also, under an atmospheric pressure, placing the wafer **1** on the placement surface **104***a* with the wax **150** interposed therebetween and thereafter fulfilling the evacuation makes it possible to remove air bubbles contained in the wax **150** and to enhance the adhesion of the wafer **1** onto the placement surface **104***a* with the wax **150** interposed therebetween. As a result of this, the heat transfer performance of the wax **150** can also be enhanced, so that heat transfer necessary for plasma processing can securely be achieved.

[**0148**] In addition, the heating of the wax **150** may also be implemented in a case where heating or cooling by giving a flow of a cooling medium or heating medium through the cooling/heating medium flow passages **44***a* or the like is done in combination with the heating by the heater electrode layer **151**. Otherwise, instead of the heating by the heater electrode layer **151**, the case may be that only the heating/cooling by the heating medium is performed.

[**0149**] The lower electrode **104** shown in **FIG. 13** is provided with the ESC layer **41** and the heat-transfer-gas supply hole $\mathbf{45}_a$. However, in an apparatus for exclusively performing the processing of wafers **1** that employ an adhesive material, since the placement position of the wafer **1** can be held by the wax **150** or the like, the ESC layer **41** can be eliminated, and moreover since the adhesion property by the wax **150** is enhanced as described above, the need for the heat-transfer-gas supply hole **45***a* can also be eliminated, thus making it implementable to simplify the construction of the plasma processing apparatus.

[**0150**] Further, a third holding method of the placement position is one in which with a weight further placed on the wafer that is placed on the placement surface **4***a*, the placement position of the wafer is held by the weight to counter the He pressure of the rear surface of the wafer **1**. A schematic perspective view of the placement surface **4***a* of the lower electrode **4** while this placement method is being performed is shown in **FIG. 5**.

[**0151**] As shown in **FIG. 5**, an abnormally shaped wafer **1***b* of a quarter disc shape is placed on the placement surface **4***a*. Also, as a weight **39**, a ring-shaped one having a circular hole **39***a* formed inside thereof is used. The weight measure of this weight **39** can be determined in consideration of the strength of the abnormally shaped wafer **1***b*, forces required for the holding of the placement position as well as for the holding of the rear surface of the wafer **1** against the He pressure, and the like. Further, the inner diameter of the circular hole **39***a* of the weight **39** and the external shape of the weight **39** are determined in consideration of the external shape of the abnormally shaped wafer **1***b* and the region subjected to plasma processing. That is, the shape of the weight **39** is so determined that, with the weight **39** placed on the abnormally shaped wafer **1***b*, the weight **39** is securely brought into contact with the peripheral portion of the abnormally shaped wafer **1***b*, making it possible to hold the placement position, while the plasma processing region in the top face of the abnormally shaped wafer **1***b* is positioned to within the circular hole **39***a* of the weight **39**, thus allowing the plasma processing through the circular hole **39***a* to be implementable. It is of course allowable that, with weights **39** of a plurality of kinds of configurations prepared beforehand, a weight **39** best suitable for the abnormally shaped wafer **1***b* is selected from among those. Such a holding method of the placement position is suited for the placement of wafers **1** which should be kept from any electrical effects due to the electrostatic chuck, and has an advantage that the placement is easier to do as compared with the case where the wafer **1** is stuck by using wax or the like.

[**0152**] According to the individual holding methods of the placement position, in any one of those methods, while the placement position of the wafer can be securely held and moreover the wafer temperature can be maintained at a temperature best suited for plasma processing, the methods are capable of managing the holding of the placement position of wafers of various configurations because the methods are not affected by the configuration of wafers, thus suitable particularly for experiment and development uses as well as for small-quantity production use.

[**0153**] In addition, instead of such cases where the above individual holding methods are performed, the case may be such one in which the wafer **1** is simply placed on the placement surface **4***a*. Even such a method is sufficient particularly in cases where high-precision plasma processing is not required.

Effects by the First Embodiment

[**0154**] According to the first embodiment, the following various working effects can be obtained.

[**0155**] First, by virtue of the arrangement that the lower electrode **4** provided at the fore end of the slide shaft **32** is

movable forward and backward between the plasma processing position A within the process chamber **2** and the wafer delivery position B within the preliminary chamber **3**, the wafer **1** can be carried to the plasma processing position A by moving the lower electrode **4** to the plasma processing position A while the wafer **1** fed at the wafer delivery position B is placed on the placement surface **4***a* of the lower electrode **4**. Also, conversely, with the wafer **1** subjected to plasma processing at the plasma processing position A, the wafer **1** can be carried to the wafer delivery position B by moving the lower electrode **4** to the wafer delivery position B.

[**0156**] Furthermore, by virtue of the provisions of the wafer delivery gate **23** and the lid **22** that make the delivery of the wafer **1** to be implemented between the placement surface **4***a* located at the wafer delivery position B in the preliminary chamber **3** and the outside of the apparatus, the feed and discharge of the wafer **1** to the placement surface **4***a* can be fulfilled directly from the outside of the apparatus.

[**0157**] Accordingly, wafers having characteristics of being thin and weak in its strength can be carried without intervention of any carrier robot that would be employed in conventional plasma processing apparatuses, so that occurrence of carrying trouble involved in the intervention of a carrier robot can be prevented, and moreover that constraints on the configuration and material of the substrate involved in the intervention of a carrier robot can be eliminated.

[**0158**] In particular, the push-up device, which would be necessary to scoop and carry the wafer placed on the lower electrode in conventional plasma processing apparatuses, can be made unnecessary in the plasma processing apparatus **100** of the first embodiment. As a result of this, occurrence of operational failures of the push-up device such as damage, drops and the like of the substrate, which would occur to conventional plasma processing apparatuses as carrying trouble, can be eliminated in the plasma processing apparatus **100**, and reliable carriage of the wafer **1** can be achieved.

[**0159**] Also, as to the issue that only disc-shaped wafers can be carried, which has been a constraint involved in the intervention of a carrier robot, since the wafer **1** can be carried as it is placed directly on the placement surface **4***a*, it becomes implementable to carry even partly disc-shaped wafers or abnormally shaped wafers or the like, so that the above issue can be solved. In particular, such abnormally shaped wafers (without being limited to wafers, jigs to which a wafer is attached are also applicable) are in many cases used for experiment and development uses and small-quantity production use, there can be provided a plasma processing apparatus suitable for such experiment and development uses and small-quantity production use.

[**0160**] Also, since plasma processing on the abnormally shaped wafer **1***b* can be carried out as the abnormally shaped wafer **1***b* is placed directly on the placement surface **4***a* without being stuck onto a disc-shaped wafer, the plasma processing can be performed without impairing the thermal conductivity on the abnormally shaped wafer **1***b*. Accordingly, there can be provided a plasma processing apparatus which is capable of performing efficient, high-precision plasma processing on such special-configuration wafers and which is suited for experiment and development uses and small-quantity production use.

[**0161**] Further, the interruption part **30** which can interrupt the communicating gate **28** by being brought into contact with the peripheral portion of the communicating gate **28**, which is the communicating opening portion between the process chamber **2** and the preliminary chamber **3** is provided near the connecting portion between the lower electrode **4** and the slide shaft **32**. Further, the interruption can be performed by locating the placement surface **4***a* to the plasma processing position A, and the release of the contact can be performed by locating the placement surface **4***a* to the wafer delivery position B. As a result, the sealing and sealing release operation of the process chamber **2** can be performed by carrying operation of the wafer **1**. Thus, the constitution of the plasma processing apparatus can be simplified to more extent, and reliable plasma processing in which occurrence frequency of faults or the like is reduced can be made implementable.

[**0162**] Also, in the plasma processing apparatus **100**, the process chamber **2** and the preliminary chamber **3** are disposed so that the preliminary chamber center axis Q is inclined against the process chamber center axis P with an inclination angle of θ. By the lower electrode **4** being movable along the preliminary chamber center axis Q while maintaining the placement surface **4***a* horizontal, i.e., being "obliquely movable," performing the move makes it possible to realize substantially "horizontal move" and "vertical move" concurrently.

[**0163**] Further, in the constitution in which the lower electrode **4** is moved along the inclined preliminary chamber center axis Q as shown above, a larger space can be ensured upward of the placement surface **4***a*, as compared with the case where only "horizontal move" is performed. As a result of this, not only workpieces of smaller configurational heights such as disc-shaped wafers **1** or the like but also workpieces of higher configurational heights can be placed on the placement surface **4***a*, so that plasma processing on workpieces of wider varieties of higher configurational heights can be realized.

[**0164**] Further, in comparison with apparatuses in which "vertical move" only is performed, an inclination of the preliminary chamber center axis Q makes it possible to provide the lid **22** on a side face of the preliminary chamber **3** upward of the placement surface **4***a* positioned at the wafer delivery position B, so that the placement surface **4***a* can be visually recognized securely from upward thereof or the wafer can be fed or extracted directly with hand through the lid **22** or with the lid **22** opened. Accordingly, in the feeding operation or extraction operation by the placement of the wafer **1**, secure feed or discharge operation can be achieved while the state (placement state, plasma processing state, etc.) of the wafer **1** is visually recognized. Such effects can be said to be suitable particularly for experiment and development uses and small-quantity production use in which abnormally shaped wafers or the like are more often used.

[**0165**] Also, by the provisions of the gate lid **24** and the gate lid opening/closing device **26** capable of sealing the process chamber **2** which is opened with the placement surface **4***a* positioned at the wafer delivery position B, the process chamber **2** can be maintained at sealed state independent of the preliminary chamber **3** even in such a case where the preliminary chamber **3** is opened for the feed or discharge of the wafer **1**. As a result of this, the interior of

the process chamber **2** can normally be maintained at an atmosphere (a state of pressure, temperature, wall-surface deposition, etc.) suitable for plasma processing, so that efficient, uniform processing can be achieved when plasma processing is performed continuously on a plurality of wafers **1**.

[**0166**] Also, the process chamber vessel **5** that forms a lower configuration of the process chamber **2** includes two planar portions, i.e. a planar portion, which is a communicating portion with the preliminary chamber **3**, and a planar portion, which is communicated with the turbo-pump **17** serving for evacuation in such a fashion that the two planar portions are coupled with each other in a V shape, thus allowing the process chamber **2** to be reduced in volume. For instance, in the case of the "horizontal move" only or the "vertical move" only, the V-shaped configuration cannot be formed, making impossible to downsize the volume, but implementing the V-shaped process chamber vessel **5** by adopting the above "oblique move" makes it possible to downsize the process chamber **2**, so that a compact apparatus can be provided.

[**0167**] Furthermore, by the use of the process chamber vessel **5** including such V-shaped coupled two planar portions, it becomes possible to ensure gas flow passages for evacuation simultaneously while the process chamber **2** is downsized, thus making it possible to achieve efficient, large-volume evacuation and to implement high-precision plasma processing.

Second Embodiment

[**0168**] The present invention, not limited to the above embodiment, may be carried out in other various modes. For example, a schematic sectional view showing a schematic construction of a plasma processing apparatus **200** according to a second embodiment of the invention is shown in **FIG. 6**.

[**0169**] As shown in **FIG. 6**, the plasma processing apparatus **200** is similar in structure and function of individual components to the plasma processing apparatus **100** of the foregoing first embodiment, but differs in constitution from the plasma processing apparatus **100** in that a process chamber **202** and a preliminary chamber **203** are so arranged that the inclination angle θ between the process chamber center axis P and the preliminary chamber center axis Q becomes generally 90 degrees.

[**0170**] As shown in **FIG. 6**, the process chamber **202** is formed of a process chamber vessel **205**, which is a generally cylindrical-shaped bottomed member, and a quartz window **212**, which can seal in a lid shape over upper part of the process chamber vessel **205**. With a proximity to a center of the process chamber **202** assumed as a plasma processing position A, a placement surface **204***a* of a lower electrode **204** can be positioned at the position. Also, a coil **206** to which a radio-frequency power is applied via a radio-frequency power supply **208** and a matcher **210** is provided in a wound state outside and upward of the quartz window **212**.

[**0171**] Further, the process chamber **202** is provided with a gas inlet **214** for introducing a specified reactant gas to the interior of the process chamber **202**, and a turbo-pump **217** for evacuating the interior of the process chamber **202**. The turbo-pump **217** is fitted to the process chamber **202** via a control valve **218**, and moreover connected to the second rotary pump **216**.

[**0172**] As shown in **FIG. 6**, the preliminary chamber **203** is disposed in adjacency to the process chamber **202** on the right side thereof as viewed in the figure, and a communicating gate **228** is formed so as to make the two chambers communicated with each other. Further provided are a gate lid **224** which can open and close the communicating gate **228**, a gate lid opening/closing device **226** and a lid housing chamber **225**. In the preliminary chamber **203**, it is made possible that the lower electrode **204** is positioned to the wafer delivery position B, which is a position near the center of the preliminary chamber **203**, and a wafer delivery gate **223** which makes it possible to deliver the wafer **1** between such positioned lower electrode **204** and the outside of the apparatus as well as a lid **222** which can open and close the wafer delivery gate **223** are disposed upward of the wafer delivery position B.

[**0173**] The lower electrode **204** is fixed at the left end, as viewed in the figure, of a slide shaft **232** located along the preliminary chamber center axis Q, and it is made possible to move the lower electrode **204** forward and backward between the plasma processing position A and the wafer delivery position B along the preliminary chamber center axis Q by moving the slide shaft **232** forward and backward along the preliminary chamber center axis Q by an air cylinder **234**.

[**0174**] Further, at the connecting portion between the lower electrode **204** and the slide shaft **232** is provided an interruption part **230** which is brought into contact with the peripheral portion of the communicating gate **228** by the lower electrode **204** being positioned to the plasma processing position A, to thereby releasably seal the process chamber **202**.

[**0175**] Also, in the preliminary chamber **203**, a second rotary pump **220** for evacuating the interior of the preliminary chamber **203** is provided. It is noted that the quartz window **214** and the lid **222** (made of, for example, acrylic resin) are transparent, thus making it possible to visually recognize the interior of the process chamber **202** and the interior of the preliminary chamber **203** from the outside of the apparatus.

[**0176**] For such a plasma processing apparatus **200**, plasma processing can be carried out by an operational procedure basically similar to that of the plasma processing apparatus **100** of the first embodiment.

Effects by the Second Embodiment

[**0177**] According to the second embodiment, like the working effects of the first embodiment, the feed and discharge of the wafer **1** can be performed while the placement surface **204***a* of the lower electrode **204** is visually recognized through the wafer delivery gate **223** in the preliminary chamber **203**. Also, by virtue of the arrangement that the lower electrode **204** itself moves, there can be provided a plasma processing apparatus which can eliminate the need for a carrier robot, wafer push-up pins or the like, which would be necessary in conventional plasma processing apparatuses, so that the frequency of occurrence of operational failures can be reduced.

[0178] Further, since the wafer 1 can be carried as the wafer 1 is placed directly on the placement surface 204a of the lower electrode 204 without intervention of a carrier robot, the plasma processing apparatus is ready for plasma processing particularly on abnormally shaped workpieces.

[0179] Further, since the move direction of the lower electrode 204 is a horizontal direction, the apparatus can be downsized in the vertical direction.

Third Embodiment

[0180] Next, a schematic sectional view showing a schematic construction of a plasma processing apparatus 300 according to a third embodiment of the present invention is shown in FIG. 7. Also, a sectional view taken along the line D-O-D in the plasma processing apparatus 300 shown in FIG. 7 is shown in FIG. 8.

[0181] As shown in FIGS. 7 and 8, the plasma processing apparatus 300 is a plasma processing apparatus which is so constructed that another preliminary chamber, another substrate electrode portion and another substrate electrode moving device are additionally provided in the plasma processing apparatus 100 of the first embodiment, that is, a plurality of preliminary chambers, a plurality of substrate electrode portions and a plurality of substrate electrode moving devices are provided for one process chamber. The plasma processing apparatus 300 is similar to the plasma processing apparatus 100 of the first embodiment in terms of the functions and uses of individual constituent components themselves, except the constituent structure that the preliminary chamber, the substrate electrode portion and the substrate electrode moving device are provided each two in quantity as shown above, and except structures related to the above constituent structure. Therefore, detailed description of the similar parts is omitted.

[0182] As shown in FIG. 7, the plasma processing apparatus 300 is provided with two preliminary chamber center axes Q1, Q2 inclined with respect to a process chamber center axis P of a process chamber 302 by an inclination angle of 45 degrees in symmetry with respect to the process chamber center axis P. Along each of the preliminary chamber center axes Q1, Q2 are provided, like the case of the plasma processing apparatus 100 of the first embodiment, preliminary chambers 303A and 303B as the two preliminary chambers, lower electrodes 304A and 304B as the two lower electrodes, and further individual constituent parts associated therewith.

[0183] Also, as shown in FIG. 8, a turbo-pump 317 serving for evacuation of the process chamber 302 is provided in connection so as to avoid the connecting portion between the two preliminary-chambers 303A and 303B in the process chamber 302. In addition, at the connecting portions between the process chamber 302 and each of the preliminary chambers 303A and 303B are provided communicating gates 328A and 328B for making those chambers with each other, respectively.

[0184] Further, the lower electrodes 304A and 304B are independently fixed to slide shafts 332A and 332B, respectively, and the slide shafts 32A and 32b can be moved independently by their respective air cylinders 334A and 334B. Also, the preliminary chambers 303A and 303B are provided with gate lids 324A and 324B, respectively, which can open and close the respective communicating gates 328A and 328B, independently.

[0185] In the plasma processing apparatus 300 having such constitution as described above, for example, with the lower electrode 304A positioned at the plasma processing position A within the process chamber 302 and with the lower electrode 304B positioned at the wafer delivery position B within the preliminary chamber 303B, the process chamber 302 and the preliminary chamber 303B can be interrupted by closing the communicating gate 328B, which is the communicating portion between the process chamber 302 and the preliminary chamber 303B. With such a state given, it becomes possible to do independent work within the process chamber 302 and the preliminary chamber 303B, respectively, without giving any influences on each other chamber. As a consequence of this, while plasma processing on the wafer 1 placed on the lower electrode 304 is carried out in the process chamber 302, the gate lid 322B is opened and delivery of the wafer 1 between the lower electrode 304B and the outside of the apparatus or other work can be carried out in the preliminary chamber 303B. Thus, it becomes implementable to achieve efficient plasma processing in the plasma processing apparatus 300.

[0186] Further, in such a case where the lower electrode 304A and the lower electrode 304B are different in kind from each other as an example, such a way of use also becomes possible as selecting an optimum lower electrode out of those lower electrodes 304A and 304B depending on the type or the like of the wafer 1 to be subjected to plasma processing. In such a case, there can be provided a plasma processing apparatus which is capable of easily and promptly making ready for a wider variety of kinds of substrates, and which can be made suitable particularly for research and development uses or small-quantity production use.

[0187] In addition, although the above description has been made on a case where the plasma processing apparatus 300 has two preliminary chambers, two substrate electrode portions and two substrate electrode moving devices, yet the third embodiment is not limited to such a case only. Instead of such a case, for example, the case may be one in which the plasma processing apparatus is provided with three or more preliminary chambers, substrate electrode portions and substrate electrode moving devices. This is because the above-described working effects can be obtained by the provision of at least two or more of those components.

[0188] Further, the above working effects can be obtained even in the case where the plurality of preliminary chambers (i.e., two or more preliminary chambers) are communicated with each other, where one preliminary chamber is disposed around one process chamber while a plurality of substrate electrode portions and substrate electrode moving devices are provided so as to be reciprocatingly movable between the one process chamber and the one preliminary chamber communicated with each other, independently of each other.

[0189] Further, although the above description has been made on a case where the two preliminary chambers 303A and 303B are disposed so as to be symmetrical to each other in the plasma processing apparatus 300, yet such symmetrical disposition is not limitative, and other various dispositions are adoptable.

Fourth Embodiment

[0190] Next, a schematic sectional view showing a schematic construction of a plasma processing apparatus **400** according to a fourth embodiment of the present invention is shown in **FIG. 9**. As shown in **FIG. 9**, the plasma processing apparatus **400** is horizontal positioned on the whole of the apparatus so that the process chamber center axis P in the plasma processing apparatus **100** of the first embodiment becomes generally horizontal. Also, the functions and uses of the individual apparatus constituent components are similar to those of the plasma processing apparatus **100**.

[0191] However, as shown in **FIG. 9**, in the plasma processing apparatus **400**, a rotary actuator **450**, which is an example of a substrate electrode rotating device for rotating a slide shaft **432**, which performs the move operation of a lower electrode **404**, about a preliminary chamber center axis Q that is the move axis of the slide shaft **432**, is provided in addition to the construction of the plasma processing apparatus **100**. It is noted that a rotating seal **451** is provided between the slide shaft **432** and a preliminary chamber **403**, by which airtightness of the preliminary chamber **403** is maintained.

[0192] By the provision of the rotary actuator **450** like this, for example, as shown in **FIG. 9**, at the wafer delivery position B, the delivery of the wafer **1** can securely and easily be achieved while the lower electrode **404** has been rotated and positioned so that a placement surface **404***a* of the lower electrode **404** becomes generally horizontal postured. Meanwhile, in the case where with the lower electrode **404** positioned at the plasma processing position A, the wafer **1** placed thereon is subjected to plasma processing, the placement surface **404***a* can be postured generally vertical by rotating the lower electrode **404** by 180 degrees by the rotary actuator **450**. By performing plasma processing on the wafer **1** in such a posture, the deposition amount of dust or the like onto the surface of the wafer **1** during the plasma processing can be reduced, so that etching surfaces or film-deposited surfaces of high quality can be formed. Further, in such a plasma processing apparatus **400**, a placement posture of the substrate by the lower electrode **404** at the wafer delivery position B, and a placement posture of the substrate by the lower electrode **404** at the plasma processing position A can be made different from each other depending on the configuration and characteristics and the like of the substrates, thus making it possible to perform plasma processing on substrates of a wider variety of configurations and characteristics.

[0193] It is to be noted that, by properly combining the arbitrary embodiments of the aforementioned various embodiments, the effects possessed by them can be produced.

[0194] Although the present invention has been fully described in connection with the preferred embodiments thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications are apparent to those skilled in the art. Such changes and modifications are to be understood as included within the scope of the present invention as defined by the appended claims unless they depart therefrom.

[0195] The entire disclosure of Japanese Patent Application No. 2003-283394 filed on Jul. 31, 2003, including specification, claims, and drawings are incorporated herein by reference in its entirety.

1. A plasma processing apparatus for generating a plasma by applying electric power and performing plasma processing on a substrate, comprising:

a process chamber in which the plasma processing is performed on the substrate placed inside thereof;

a preliminary chamber which is a chamber intervening between the process chamber and outside of the apparatus and which has a lid portion for interrupting the preliminary chamber from the outside of the apparatus by closing thereof and for allowing the substrate to be delivered between the outside of the apparatus and interior of the preliminary chamber by opening thereof;

an evacuator for evacuating each of interior of the process chamber and the interior of the preliminary chamber to draw a vacuum;

a reactant gas supply portion for supplying reactant gas into the process chamber;

a substrate electrode portion having a substrate placement surface on which the substrate is to be placed, for performing temperature control of the placed substrate by heat transfer through the substrate placement surface during the plasma processing;

an electric power applying device for applying radio-frequency power or DC power as the electric power to a coil or an electrode provided in or on the process chamber; and

a substrate electrode moving device for moving the substrate electrode portion forward and backward between a plasma processing position where the plasma processing is performed on the substrate placed on the substrate placement surface in the process chamber that has been evacuated by the evacuator and to which the reactant gas has been supplied by the reactant gas supply portion and in which a plasma has been generated by applying the electric power to the coil or electrode by the electric power applying device, and a substrate delivery position where the substrate is delivered through the opened lid portion between the outside of the apparatus and the substrate placement surface within the preliminary chamber.

2. The plasma processing apparatus as defined in claim 1, wherein the preliminary chamber is placed along a direction inclined with respect to a center axis of the process chamber; and

the substrate electrode moving device is operable to move the substrate electrode portion between the plasma processing position and the substrate delivery position along a move axis set along the inclined direction.

3. The plasma processing apparatus as defined in claim 2, wherein an angle of the inclination is any one within a range of 30 to 60 degrees.

4. The plasma processing apparatus as defined in claim 1, wherein the preliminary chamber is placed along a generally horizontal direction which is a direction generally perpendicular to a center axis of the process chamber; and

the substrate electrode moving device is operable to move the substrate electrode portion between the plasma

processing position and the substrate delivery position along a move axis set along the generally horizontal direction.

5. The plasma processing apparatus as defined in claim 1, wherein the lid portion is placed so as to allow the substrate placement surface of the substrate electrode portion positioned at the substrate delivery position to be visually recognized from the outside of the apparatus, and allow the substrate to be placed onto the substrate placement surface directly from the outside of the apparatus, in its opened state.

6. The plasma processing apparatus as defined in claim 1, further comprising:

a communicating gate portion for making the process chamber and the preliminary chamber communicated with each other so as to allow the substrate electrode portion with the substrate placed thereon to pass through the communicating gate portion; and

a process chamber interruption part which is movable integrally with the substrate electrode portion and which, with the substrate electrode portion positioned to the plasma processing position, closes the communicating gate portion to interrupt the process chamber and the preliminary chamber from each other, and with the substrate electrode portion positioned to the substrate delivery position, opens the communicating gate portion to release the process chamber and the preliminary chamber from the interruption, thereby making the process chamber and the preliminary chamber communicated with each other.

7. The plasma processing apparatus as defined in claim 5, further comprising an interruption device having an openable/closable gate lid for closing the communicating gate portion to interrupt communication between the process chamber and the preliminary chamber, with the substrate electrode portion positioned to the substrate delivery position.

8. The plasma processing apparatus as defined in claim 7, further comprising:

at least two preliminary chambers communicated with the one process chamber;

at least two substrate electrode portions which are movable forward and backward between the substrate delivery position in each of the preliminary chambers and the plasma processing position in the process chamber; and

at least two communicating gate portions which make the process chamber and each of the preliminary chambers communicated with each other, wherein

the substrate electrode moving device is operable to position one substrate electrode portion selected out of the substrate electrode portions to the plasma processing position and to position the other substrate electrode portion to the substrate delivery position, and

the interruption device is operable to close and interrupt the communicating gate that serves for communication between the process chamber in which the one substrate electrode portion is positioned and the preliminary chamber in which the other substrate electrode portion is positioned.

9. The plasma processing apparatus as defined in claim 2, further comprising a substrate electrode rotating device for rotating the substrate electrode portion about a rotational center that is given generally by the move axis of the substrate electrode portion by the substrate electrode moving device, wherein

the substrate placed on the substrate placement surface differs in placement posture between its one placement posture at the substrate delivery position and its another processing posture at the plasma processing position.

10. The plasma processing apparatus as defined in claim 1, further comprising a substrate delivery device for performing delivery of the substrate between the substrate placement surface of the substrate electrode portion positioned at the substrate delivery position and the outside of the apparatus.

11. The plasma processing apparatus as defined in claim 1, wherein holding of a placement position of the substrate to the substrate placement surface is fulfilled by an adhesive material which is interposed between the substrate and the substrate placement surface, and by which close contact between the substrate and the substrate placement surface is facilitated by the interior of the preliminary chamber being evacuated by the evacuator, and which allows heat transfer between the substrate and the substrate placement surface for the plasma processing.

12. The plasma processing apparatus as defined in claim 11, wherein the substrate electrode portion further comprises a heating device for performing temperature control of the substrate in the process chamber and heating the substrate placement surface,

the heating device is operable to:

for feeding the substrate in the preliminary chamber, heat the adhesive material through the substrate placement surface to melt or soften the adhesive material so that the substrate placed on the substrate placement surface and the substrate placement surface are brought into close contact with each other via the adhesive material;

for plasma processing of the substrate in the process chamber, perform solidification of the melted or softened adhesive material by lowering temperature of the heating, thereby fixing the close contact between the substrate and the substrate placement surface via the adhesive material and further fulfilling the temperature control of the substrate by heat transfer through the substrate placement surface and the adhesive material; and

for discharging of the substrate in the preliminary chamber, heat the adhesive material once again to melt or soften the solidified adhesive material, thereby aiding release of the fixing of the close contact between the substrate and the substrate placement surface by the adhesive material.

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